21 February 2013

MEMORANDUM

To: Ellen Belk, EPA Region 6
Cc: Susan Wolf, RTI International
From: Uarporn Nopmongcol, Greg Yarwood
Subject: 2002 Baseline CAMx Simulation, Texas Regional Haze Evaluation
[Contract EP-W-011-029]

ENVIRON is assisting EPA by evaluating regional haze impacts of selected sources in Texas. The analysis builds upon modeling of 2002 conducted previously for CENRAP by ENVIRON. The CENRAP database was enhanced to include a 12 km grid over Texas and nearby Class I areas, and updated to use with the latest version of the Comprehensive Air Quality Model with extensions (CAMx; ENVIRON, 2012). This memorandum documents the new 2002 baseline modeling setup and results.

INTRODUCTION

The Clean Air Act (CAA) establishes special goals for visibility in many national parks, wilderness areas, and international parks. Through the 1977 amendments to the Clean Air Act, Congress set a national goal for visibility as "the prevention of any future, and the remedying of any existing, impairment of visibility in mandatory Class I Federal areas which impairment results from manmade air pollution" (40 CFR 51.300). The goal of the Regional Haze Rule (RHR) is to achieve natural visibility conditions at 156 Federally mandated Class I areas by 2064. To achieve this goal, the RHR has set up milestone years of 2018, 2028, 2038, 2048, 2058, and 2064 to monitor progress toward natural visibility conditions. The 2000-2004 five-year baseline has been used by states to demonstrate progress toward natural visibility conditions in 2018.

EPA Region 6 is presently under a court-ordered Consent Decree deadline regarding action on the Texas Regional Haze (RH) State Implementation Plan (SIP). Regional haze is linked to fine particulate matter ($PM_{2.5}$), for which EPA has a new standard. Air quality modeling is an important tool for determining whether a source can be reasonably expected to contribute to visibility impairment at a Class I area. ENVIRON is assisting EPA to evaluate regional haze impacts of sources in Texas that may be used to support the Texas Regional Haze Implementation Plan.

The Texas Haze analysis was built upon the regional photochemical modeling (ENVIRON and CERT, 2007) conducted for CENRAP. In particular, the CENRAP 2002 and 2018 36 km modeling database for CAMx was enhanced to include a 12 km grid over Texas and nearby Class I areas. The overall approach to the project includes the following steps:

- Update CENRAP 2002 and 2018 modeling database to use with the latest release of CAMx (v5.40)
- Conduct 2002 modeling with Plume-in-Grid (PiG) and a 12-km flexi-nest grid to provide the new 2002 baseline RH modeling
- Conduct 2018 modeling with PiG and the CAMx PM Source Apportionment Technology (PSAT) for target sources (selected by EPA)
- Evaluate impact of target sources on visibility in Class I areas
- Conduct any additional future-year scenarios to access various control strategies (to be determined)

This memorandum documents the new 2002 baseline modeling setup and results.

CAMx MODELING APPROACH

Air quality modeling was performed with version 5.41 of the Comprehensive Air quality Model with extensions (CAMx; ENVIRON, 2012) with input data developed by CENRAP. Several features have been introduced to CAMx since CENRAP modeling, thus, many CAMx inputs had to be updated. CAMx Input development and updates are described separately below.

2002 Annual 36 km CENRAP modeling database

The Texas Haze analysis was built upon the 2002 annual regional photochemical modeling database developed as part of the CENRAP (ENVIRON and CERT, 2007). CENRAP developed a 2002 annual modeling database for CAMx on the 36 km unified national Regional Planning Organization (RPO) grid that covers the continental United States. The CENRAP modeling protocol (Morris et al., 2004), CENRAP modeling Quality Assurance Program Plan (QAPP; Morris and Tonnesen, 2004), and base model evaluation (ENVIRON and CERT, 2007) reports provide details on the development of the CENRAP 200236 km annual modeling database. Emissions inputs were based on 2002 Base G Typical (Typ02G) annual emissions database. Numerous iterations of the emissions modeling were conducted using interim databases before arriving at the final Base G emission inventories (e.g., Morris et al., 2005).

Enhancement to the CENRAP 2002 Modeling Database

The CENRAP Base G 2002 36 km annual CAMx photochemical modeling database was updated to include a 12 km nested-grid that covers Texas and Class I areas in and near Texas including:

- National Parks: Big Bend (BIBE), Guadalupe Mountains (GUMO), and Carlsbad Caverns;
- Wildlife Refuges: Salt Creek (SACR) and Wichita Mountains (WIMO);
- Wilderness Areas: Breton (BRET), White Mountain (WHIT), Caney Creek (CACR), Upper Buffalo (UPBU), Bandeller (BAND), Hercules-Glade (HEGL), and others (see Table 1).

Figure 1 displays the 36/12 km nested grid structure used for the CAMx modeling. The locations of the Interagency Monitoring of Protected Visual Environments (IMPROVE) sites that includes Class I areas within the 12 km modeling domain are shown in Figure 2. The CAMx flexi-nesting feature was used to specify a 12 km Texas fine grid within the CENRAP 36 km modeling domain. Full flexi-nesting was invoked in which CAMx internally interpolates meteorological data, gridded emissions and other inputs from the 36 km grid to the 12 km grid. Flexi-nesting does not interpolate point source emissions because exact source coordinates are known enabling each point source to be placed within the correct 36 km or 12 km grid cell.

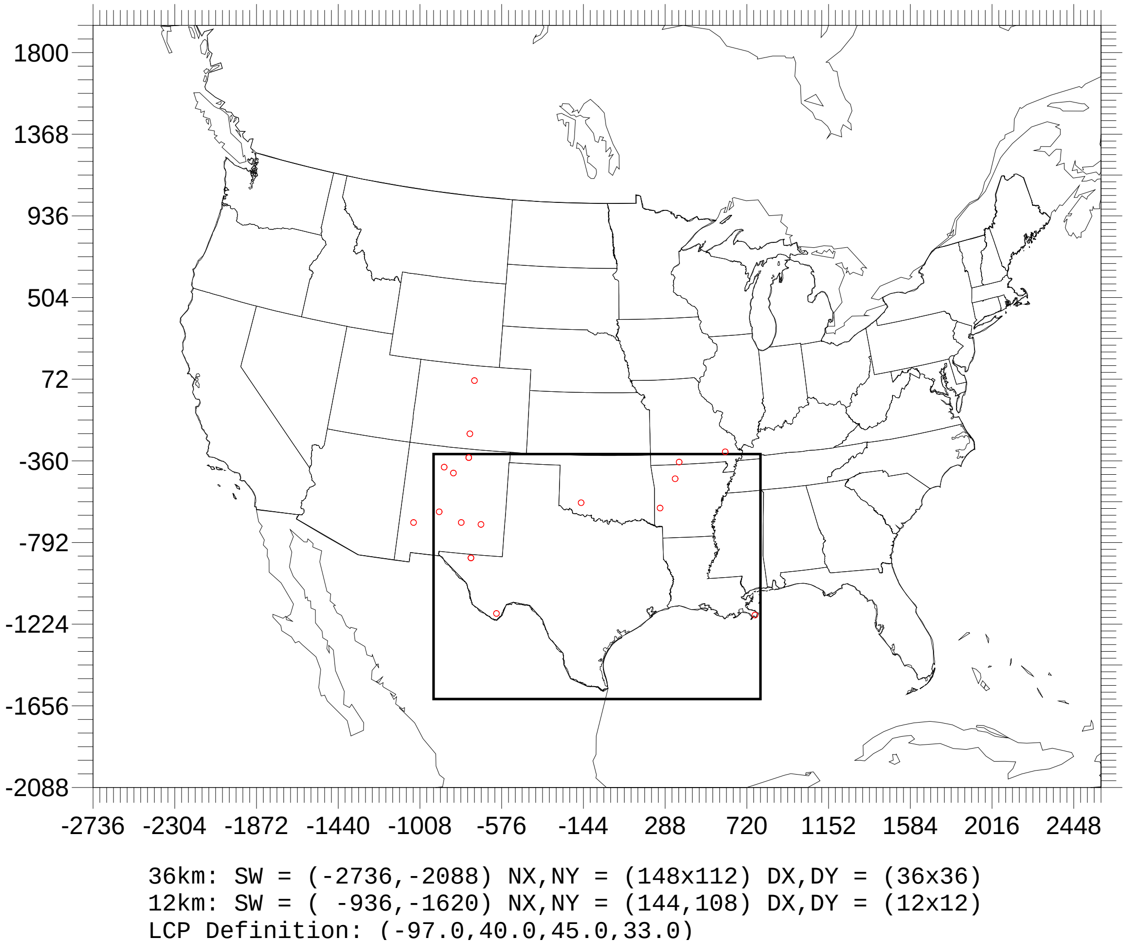


Figure 1. Texas RH modeling 36/12 km modeling domain and the locations of the IMPROVE monitoring sites that include Class I areas, indicated by circles.

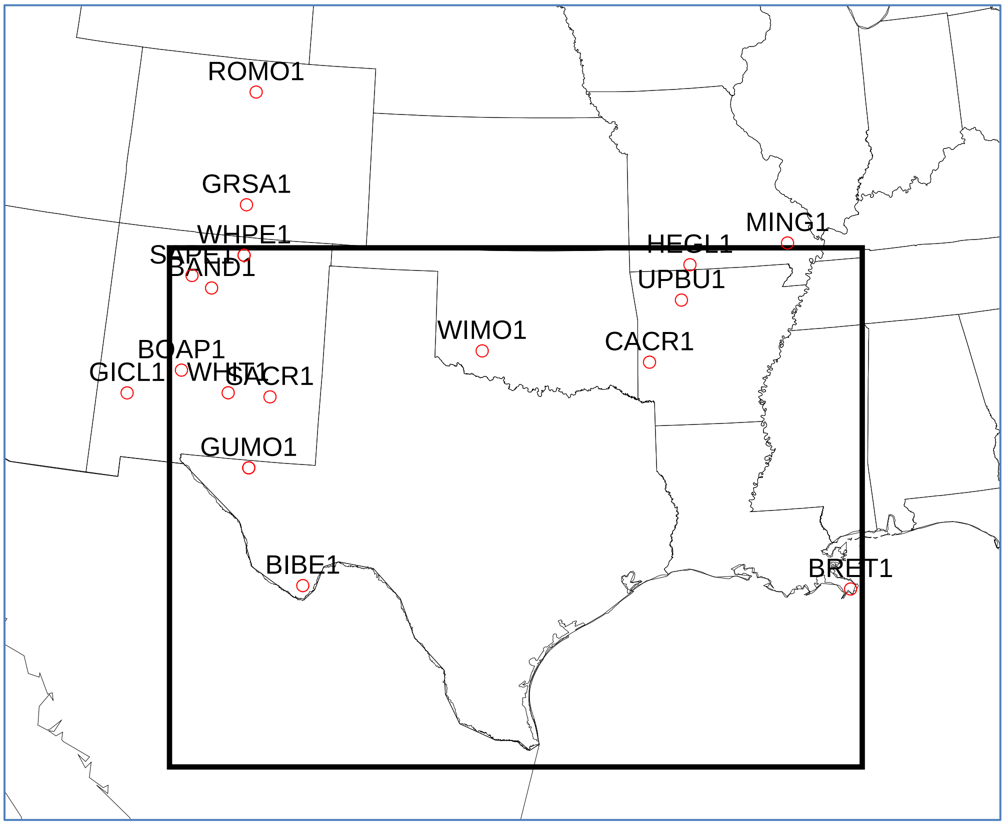


Figure 2. Texas RH modeling 12 km modeling domain and the locations of the IMPROVE monitoring sites (circles) that include Class I areas.

Table 1. Class I areas to be included in the Texas RH analysis.

Site	State	Code	State FIPS	County	County FIPS	Latitude	Longitude	LCPX (km)	LCPY (km)	Grid
Breton Wilderness Area	LA	BRET1	22	St. Bernard Parish	87	29.1189	-89.2066	763	-1176	12km
Big Bend National Park	TX	BIBE1	48	Brewster County	43	29.3027	-103.178	-604	-1167	12km
Guadalupe Mountains	TX	GUMO1	48	Culberson County	109	31.833	-104.809	-738	-873	12km
Wichita Mountains Wilderness	OK	WIMO1	40	Comanche County	31	34.7323	-98.713	-156	-581	12km
Caney Creek Wilderness Area	AR	CACR1	5	Polk County	113	34.4544	-94.1429	261	-610	12km
Upper Buffalo Wilderness Area	AR	UPBU1	5	Newton County	101	35.8258	-93.203	341	-455	12km
Bandelier Wilderness Area	NM	BAND1	35	Los Alamos County	28	35.7797	-106.266	-831	-424	12km
Bosque del Apache Wilderness Area	NM	BOAP1	35	Socorro County	53	33.8695	-106.852	-906	-629	12km
Carlsbad Caverns NP.	NM	GUMO1				31.833	-104.809	-738	-873	12km
Gila Wilderness Area	NM	GICL1	35	Catron County	3	33.2204	-108.235	-1042	-686	36km
Pecos Wilderness Area	NM	WHPE1				36.5854	-105.452	-750	-343	12km
Salt Creek Wilderness Area	NM	SACR1	35	Grant County	17	33.4598	-104.404	-685	-696	12km
San Pedro Parks Wilderness Area	NM	SAPE1	35	Rio Arriba County	39	36.0139	-106.845	-880	-393	12km

Site	State	Code	State FIPS	County	County FIPS	Latitude	Longitude	LCPX (km)	LCPY (km)	Grid
Wheeler Peak Wilderness Area	NM	WHPE1	35	Taos County	55	36.5854	-105.452	-750	-343	12km
White Mountain Wilderness Area	NM	WHIT1	35	Lincoln County	27	33.4687	-105.535	-790	-686	12km
Hercules-Glades Wilderness Area	MO	HEGL1	29	Taney County	213	36.6138	-92.9221	362	-366	12km
Mingo	MO	MING1	29	Stoddard County	207	36.9717	-90.1432	606	-312	36km
Great Sand Dunes	CO	GRSA1	8	Saguache County	109	37.7249	-105.519	-744	-217	36km
Rocky Mountain National Park	CO	ROMO1	8	Larimer County	69	40.2783	-105.546	-720	65	36km

Preparing Emissions Data

CENRAP processed emission inputs using the Sparse Matrix Operator Kernel Emissions (SMOKE) version 2.3 with chemical speciation for the CB4 mechanism. Several versions of SMOKE have been released since then. This study used the latest SMOKE version 3.1, although some SMOKE modules came from an older version to avoid incompatibility of input format. All SMOKE configurations and SMOKE input files were the same as used in CENRAP with selected updates. Provided below is a summary of the emission updates made to the CENRAP database for use in this Texas Haze analysis.

- Used CB05 chemical speciation profiles for area and point sources
- Processed point source emissions in CAMx input format to preserve stack parameters and location
- Changed the earth sphere variable (IOAPI_ISPH) in SMOKE from 19 to 20. CENRAP SMOKE setup used IOAPI_ISPH=19 that could cause inconsistencies between point source locations and the meteorological points. IOAPI_ISPH=20 assumes a 6740 km earth radius consistent with MM5 and CAMx
- Tagged Plume-in-Grid (PiG) for large SO_2 and NOx sources
- Added SOA emissions from biogenic sources based on CENRAP BEIS CB4 emissions
- Adjusted POC to POA mass

The criteria used for elevated point and PiG source selection are described below:

Non-Target sources

- A plume rise cutoff of 50 meter (i.e., any source having lower than 50 m. estimate was treated as a surface source).
- Various NOx emissions thresholds for PiG selection: 5 tons per day (TPD) for Texas, 10 TPD for neighboring states (NM, CO, OK, AR, LA, and KS), and 20 TPD for the rest.

Target sources

- All target sources were treated as elevated sources
- PiG criteria are stack height of 50 ft (~15 m.) and NOx or SO2 emissions higher than 20 TPD

Table 2 provides an emission summary for target sources.

Table 2. Annual emissions (TPY) of target sources by pollutant in the CENRAP 2002 Typical G inventory.

Number	Plant Name	FIPS	Plant ID	NOX	CO	VOC	SO2	$PM_{2.5}$	PM_{10}
1	BIG BROWN	48161	2	7,213	20,553	134	77,860	395	933
2	BIG SPRING CARBON BLACK	48227	2	629	3,927	38	9,880	5	76
3	BORGER CARBON BLACK	48233	1	483	10,351	340	3,609	69	96
4	BORGER CARBON BLACK PLT	48233	2	822	757	3	5,148	110	242
5	COLETO CREEK PLANT	48175	2	3,563	500	60	14,289	84	173
6	FAYETTE POWER PROJECT	48149	5	19,120	1,778	231	31,798	432	1,454
7	FULLERTON GAS PLANT	48003	10	1,470	759	326	2,375	23	23
8	GIBBONS CREEK	48185	2	2,218	54	58	10,816	130	295
9	GOLDSMITH GASOLINE PLANT	48135	22	888	551	204	1,597	7	7
10	GREAT LAKES CARBON LLC	48245	23	824	43	5	9,795	178	245
11	GUADALUPE COMPRESSOR STATION	48109	5	668	102	1	2	4	4
12	HARRINGTON STATION	48375	22	13,140	1,119	149	26,967	41	2,178
13	HOLCIM (TEXAS) LP	48139	22	4,204	5,052	627	3,167	378	379
14	HW PIRKEY POWER PLT	48203	22	4,953	30,216	58	19,476	405	799
15	KEYSTONE COMPRESSOR STN.	48495	30	2,870	619	61	0	19	19
16	KEYSTONE PLANT	48495	6	2,208	359	134	526	29	29
17	LIGNITE-FIRED POWER PLANT	48013	7	6,702	1,089	37	13,167	69	225
18	MARTIN LAKE ELECTRICAL STATION	48401	11	18,473	47,553	257	66,402	593	881
19	MIDLOTHIAN PLANT	48139	9	4,221	763	43	2,099	115	301
20	MONTICELLO STM ELE STN	48449	3	15,924	38,339	245	86,236	1,446	3,297
21	NEWMAN STATION	48141	8	1,717	552	38	5	63	63
22	NORTH TEXAS CEMENT CO.	48139	2	2,572	418	15	4,434	349	451
23	ODESSA CEMENT PLANT	48135	23	1,758	1,296	119	329	136	291
24	OKLAUNION POWER STATION	48487	10	8,711	363	14	3,751	171	392
25	PEGASUS GAS PLANT	48329	6	2,095	423	199	84	7	7
26	RELIANT ENERGY LIMESTONE	48293	10	13,461	1,021	232	29,268	496	546
27	SANDOW STEAM ELECTRIC	48331	5	7,681	4,059	67	23,327	649	735
28	SHERHAN PLANT	48195	6	2,419	727	294	537	34	34
29	SOMMERS DEELY SPRUCE PWR	48029	63	10,915	2,020	147	26,301	745	1,513
30	STREETMAN PLANT	48349	11	691	215	284	3,468	104	187
31	TEXARKANA MILL	48067	5	1,619	788	1,322	374	521	578
32	TNP ONE STEAM ELECTRIC ST	48395	13	2,400	823	2	5,088	153	318
33	TOLK STATION	48279	18	12,117	1,087	143	24,874	139	1,183
34	W A PARISH STATION	48157	5	15,903	8,027	163	60,238	992	1,026
35	WAHA PLANT	48389	2	478	271	48	3,386	42	42
36	WELSH POWER PLANT	48449	5	13,316	35,744	107	35,838	2,581	2,585
37	WORKS NO 4	48485	15	5,317	12	1	371	377	396

Preparing Other CAMx Inputs

Meteorological data were from the MM5 prognostic meteorological model for the calendar year of 2002. The CENRAP meteorological modeling utilized data assimilation to incorporate observations into the MM5 simulations. MM5 provided CAMx with hourly input data for winds, temperature, clouds, precipitation and vertical mixing. MM5CAMx version 5.2 was used to reduce 34 MM5 vertical layers to 19 CAMx layers.

Several GIS and Perl-based processors were used to prepare landcover and Leaf Area Index (LAI) input datasets for CAMx. This new landcover format is required in new Zhang deposition scheme in CAMx.

Albedo-Haze-Ozone Inputs (AHO files) were updated to include snow cover and allow inline TUV cloud and aerosol adjustments.

The photolysis rates were generated for CB05 chemistry using the updated AHO files. The TUV program reads the categorical values in each AHO file and creates a lookup table listing the photolysis rates for each combination of the categorical values of albedo, haze, and ozone column at various solar angles and heights above the ground.

Other inputs including boundary conditions and initial conditions were from the CENRAP database.

CAMx Model Configuration

CAMx v5.41 was chosen for this study because it was the most recent version at the time modeling task was initiated. The CAMx configuration is shown in Table 3. CENRAP CAMx configurations also are provided in Table 3 for comparison. The CAMx model was run separately for each of four quarters of 2002 using a 15 day spin up period to limit the influence of the assumed initial concentrations.

Table 3. Model Configurations Options for CAMx model.

Science Options	Texas RH	CENRAP
Version	Version 5.41	Version 4.40
Vertical Grid Mesh	19 Layers	19 Layers
Horizontal Grids	36/12 km using two-way nesting	36 km
Initial Conditions	15 days full spin-up	15 days full spin-up
Boundary Conditions	2002 GEOS-CHEM day specific 3-hour average data	2002 GEOS-CHEM day specific 3-hour average data
Sub-grid-scale Plumes	PiG treatment	No Plume-in-Grid (PiG)
Chemistry		
Gas Phase Chemistry	CB05	CB4 with isoprene updates
Aerosol Chemistry	ISORROPIA equilibrium	ISORROPIA equilibrium
Secondary Organic Aerosols	SOAP	SOAP
Cloud Chemistry	RADM-type aqueous chemistry	RADM-type aqueous chemistry

Science Options	Texas RH	CENRAP
Meteorological Processor	MM5CAMx v5.2	MM5CAMx v1
Horizontal Transport		
Eddy Diffusivity Scheme	K-theory with Kh grid size dependence	K-theory with Kh grid size dependence
Vertical Transport		
Eddy Diffusivity Scheme	K-Theory	K-Theory
Diffusivity Lower Limit	Kzmin = 0.1 to 1.0 (Land use dependent Kzmin)	Kzmin = 0.1 to 1.0 (Land use dependent Kzmin)
Planetary Boundary Layer	From MM5 with PBL below convective clouds raised to cloud top	From MM5
Deposition Scheme	Zhang	Wesely
Numerics		
Gas Phase Chemistry Solver	Euler Backward Iterative (EBI) solver	CMC fast solver
Horizontal Advection Scheme	Piecewise Parabolic Method (PPM scheme)	Piecewise Parabolic Method (PPM) scheme
Parallelization	OMP-MPI	OMP

CAMx MODELING RESULTS

Air quality modeling results for the 2002 baseline simulations are presented by pollutant of concern, including ozone and PM. The analysis of air quality results focus on high ozone and PM levels, i.e. maximum 8-hour ozone and maximum 24-hour PM. Annual average levels for PM and its constituents are also presented. Visibility analysis comparing model results to the observational data is provided at the end of this section. This project did not include a complete statistical performance evaluation.

Ozone

The annual maximum 8-hour ozone may be susceptible to model artifacts and so we focus on the annual 4th highest 8-hour ozone (Figure 3). The 2002 baseline shows high values of 4th highest daily maximum 8-hour ozone (above 75 ppb, the current level of the ozone NAAQS) in several western locations such as California, Colorado and Arizona. Much of this western ozone is associated with wildfire emissions that can be identified by their smoke plumes (i.e., high organic PM). These wildfire emissions also contain high levels of NOx which is an ozone precursor. High ozone concentrations (above 100 ppb) also occur over water bodies close to major urban/industrial areas near the Great Lakes, Gulf Coast and the Northeast Seaboard, where emissions are transported over water and confined to a shallow boundary layer. Ozone exceeds 75 ppb in several urban areas in Texas including Dallas, Houston, and San Antonio. New Orleans and Baton Rouge, Louisiana, also exceed over 75 ppb.

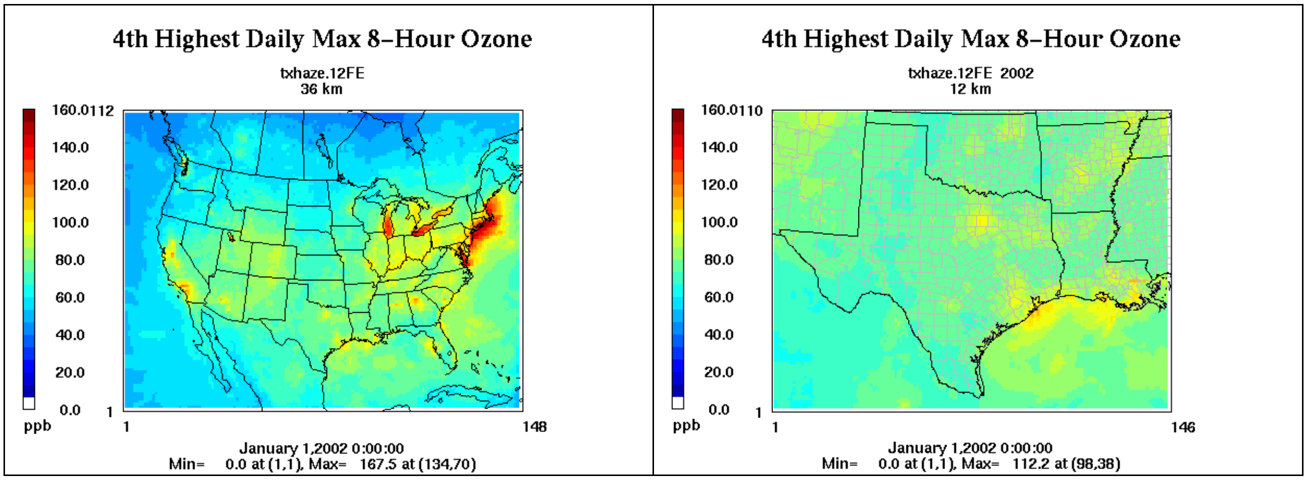


Figure 3. 4th highest daily maximum 8-Hour ozone (ppb) from the 36-km simulation (left) and 12-km simulation (right) for the 2002 baseline.

Particulate Matter

$PM_{2.5}$ results are presented for daily design-value relevant measures (98th percentile of all daily concentrations) and annual average concentrations. The baseline 8th highest 24-hour average concentrations of fine $PM_{2.5}$ (Figure 4) shows the highest peak values occurring in the Western United States but more uniformly high values occurring in the Eastern United States. Elevated $PM_{2.5}$ concentrations in the 12 km domain are seen in western Louisiana and western Arkansas. Upon inspecting emissions it appears that intense fire activities in these areas are the major cause of the high modeled PM concentrations. The causes of the high modeled PM concentrations may also be inferred from the chemical composition of the PM (shown in Appendix A). Some peaks in the Western United States occur in urban areas, such as Los Angeles and Seattle (characterized by high nitrate and organic carbon) whereas others are associated with prescribed burn and wildfire emissions (indicated by high primary organic carbon). High particulate matter concentrations in the Eastern United States have large sulfate and nitrate contributions with additional contributions from primary organic PM in the south. Annual average concentrations of $PM_{2.5}$ and PM_{10} (Figure 5 and Figure 6) show a similar pattern of widespread but the fire influence is less pronounced.

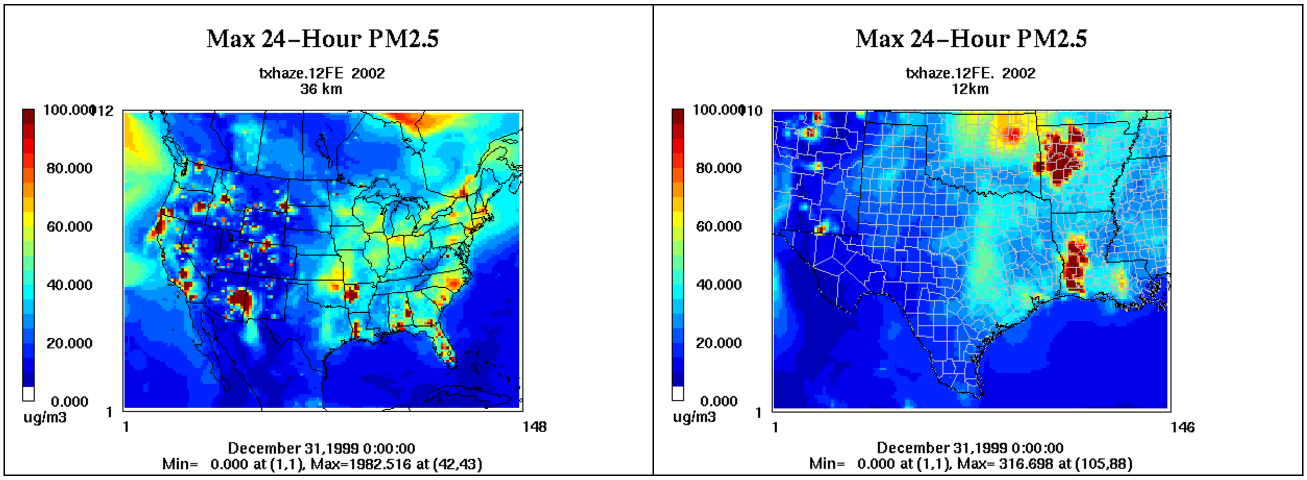


Figure 4. Maximum 24-Hour PM2.5 (µg m-3) from the 36-km simulation (left) and 12-km simulation (right) for the 2002 baseline.

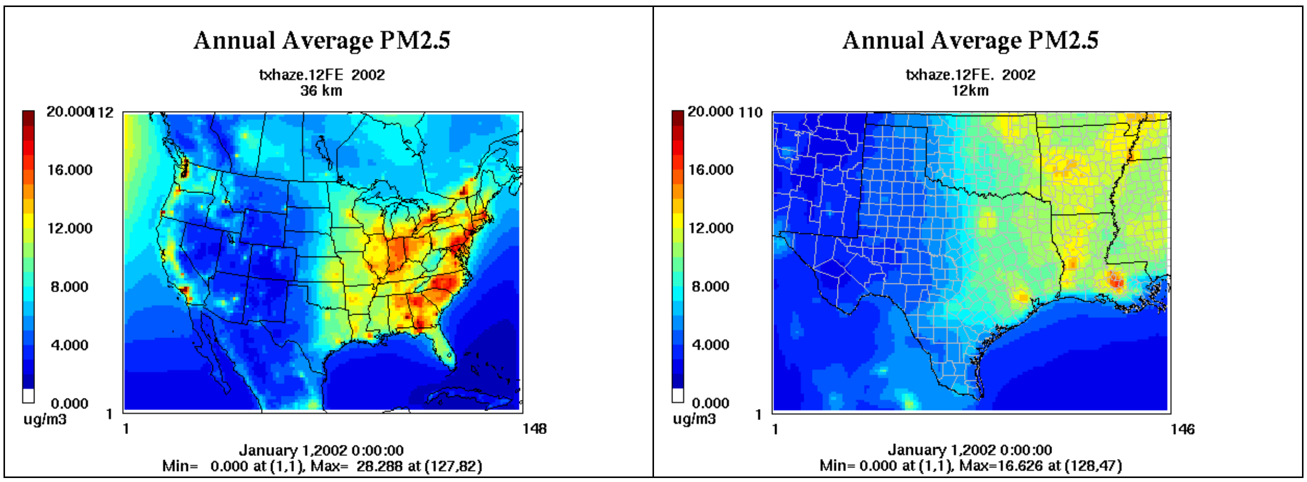


Figure 5. Annual average PM2.5 (µg m-3) from the 36-km simulation (left) and 12-km simulation (right) for the 2002 baseline.

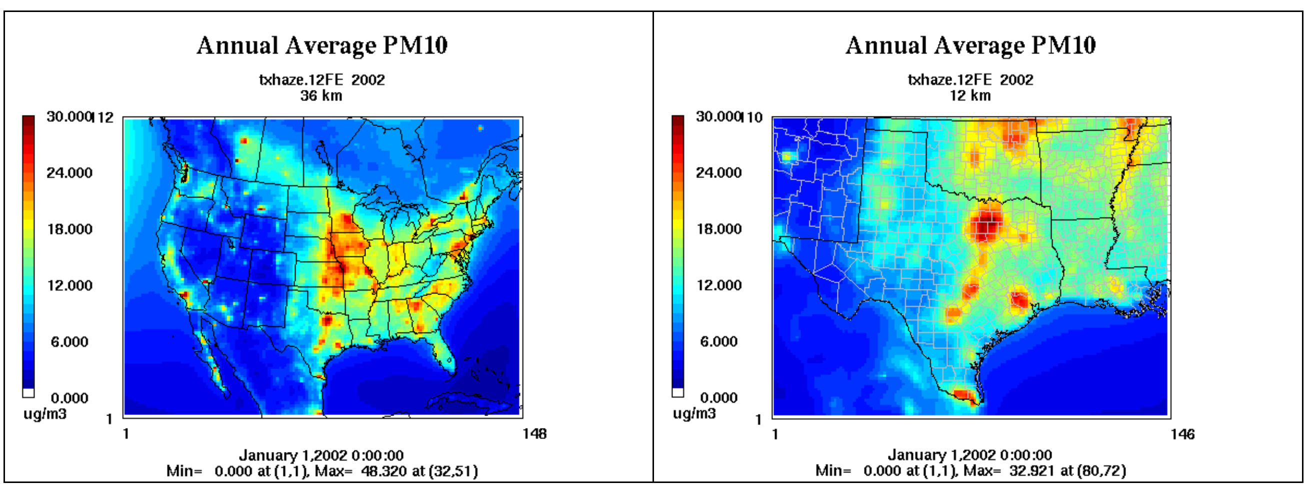


Figure 6. Annual average PM10 (µg m-3) from the 36-km simulation (left) and 12-km simulation (right) for the 2002 baseline.

Visibility

The IMPROVE algorithm for estimating light extinction from PM data has been a useful tool for understanding haze in terms of the various PM components of aerosols. EPA adopted this algorithm as the basis for the regional haze metric for visibility impact calculations under the 1999 RHR. This work used the new IMPROVE algorithm (Pitchford et al., 2007) which reconstructs the light-extinction coefficient (bext, expressed in units of inverse megameters, Mm-1) using the following equation:

$$
\begin{gathered}
\text{bext} \approx \\
2.2 \times f_S(RH) \times [\text{small sulfate}] + 4.8 \times f_L(RH) \times [\text{large sulfate}] \\
+ 2.4 \times f_S(RH) \times [\text{small nitrate}] + 5.1 \times f_L(RH) \times [\text{large nitrate}] \\
+ 2.8 \times [\text{small organic mass}] + 6.1 \times [\text{large organic mass}] \\
+ 10 \times [\text{elemental carbon}] \\
+ 1 \times [\text{fine soil}] \\
+ 1.7 \times f_{SS}(RH) \times [\text{sea salt}] \\
+ 0.6 \times [\text{coarse mass}] \\
+ \text{Rayleigh scattering (site-specific)} \\
+ 0.33 \times [NO_2 \text{ (ppb)}]
\end{gathered}
$$

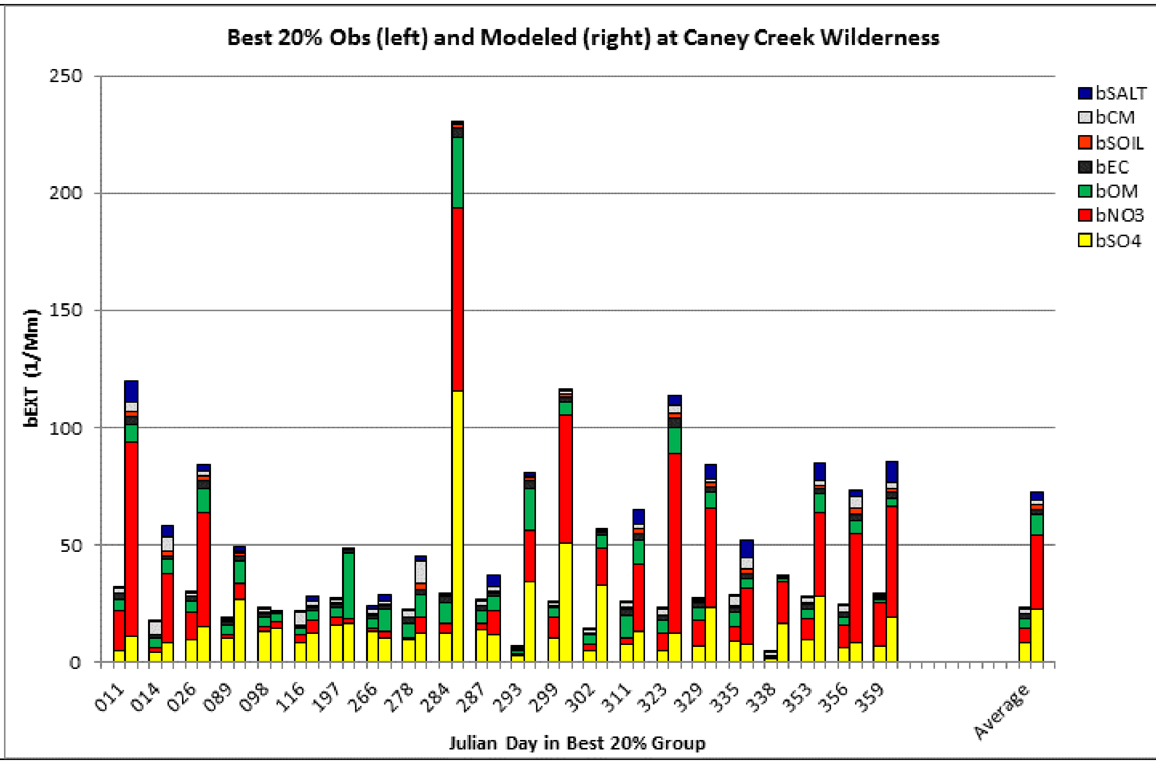
The apportionment of the total concentration of sulfate compounds into the concentrations of small and large size fractions is accomplished using the following equations:

$$
\begin{gathered}
[\text{large sulfate}] = [\text{total sulfate}/20] \times [\text{total sulfate}], \text{ for } [\text{total sulfate}] < 20\ \mu g/m3 \\
[\text{large sulfate}] = [\text{total sulfate}], \text{ for } [\text{total sulfate}] \geq 20\ \mu g/m3 \\
[\text{small sulfate}] = [\text{total sulfate}] - [\text{large sulfate}]
\end{gathered}
$$

The same equations are used to apportion total nitrate and total organic mass into small and large size fractions. The new algorithm contains three distinct water growth terms, designated f_S, f_L, and f_{SS} for the small and large sulfate and nitrate fractions, and for sea salt, respectively. Monthly average f(RH) values are used as following FLAG2010 procedure (FLAG, 2010).

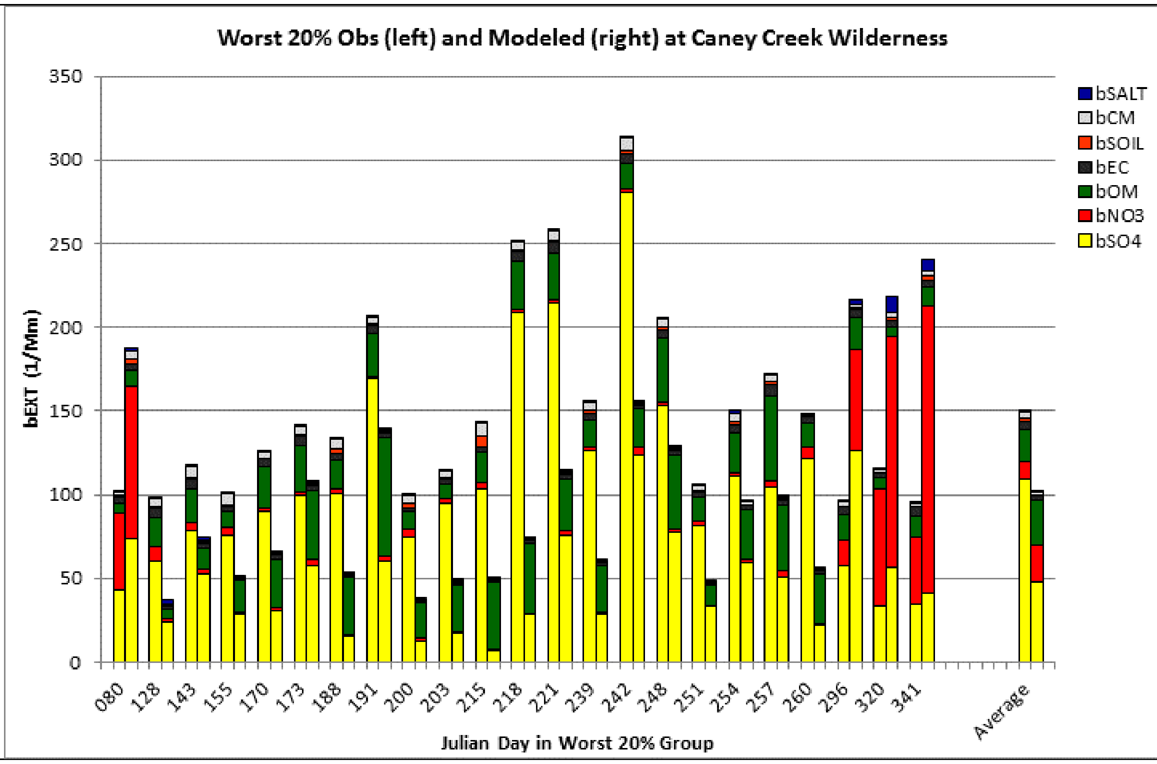
EPA's visibility natural conditions guidance document lists three default natural condition values corresponding to best 20% (B20%) days, worst 20% (W20%) days, and annual average (EPA, 2003b). Our analysis calculates the 2002 visibility and compares to the measurements at Class I areas on the B20% and W20% days. Similar analysis based on CMAQ simulation results was conducted by CENRAP for the worst 20% days and documented in Appendix D of the CENRAP Technical Support Document (ENVIRON and CERT, 2007). CENRAP analysis on the W20% days was provided here for comparison.

Figures 7-10 demonstrate visibility comparisons at the Class I areas in Texas (i.e., Big Bend and Guadalupe Mountains) and nearby Texas (i.e., Caney Creek and White Mountain). Additional visibility comparison for other sites can be found in Appendix B. Performance for the B20% days is mostly characterized by an overestimation bias; whereas the W20% days is characterized by an underestimation bias. Measurement data show that on average sulfate dominates light-extinction coefficient on both B20% and W20% cases, however model results show variation of dominant light-extinction component. On the W20% days, underestimation of sulfate is observed across all sites. The sulfate underestimation was also seen in the CENRAP analysis. Soil performance on the B20% days at CACR and WIMO Class I areas is suspect and care should be taken in the interpretation of the visibility projections at these Class I areas.

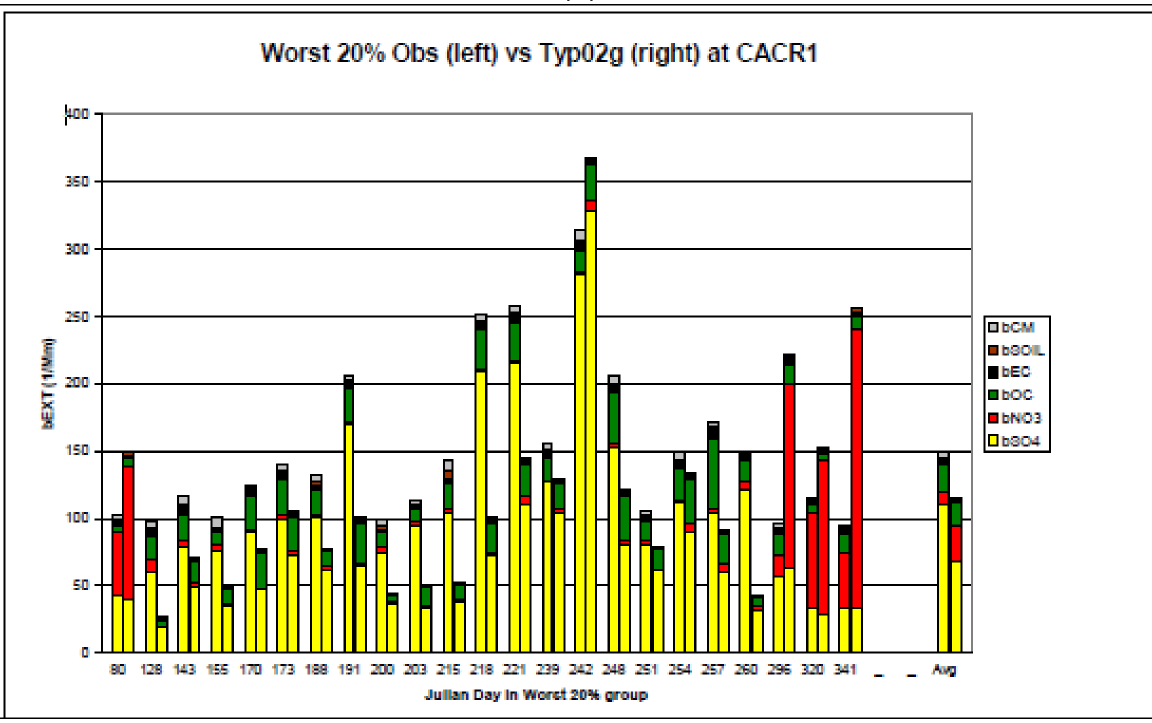


(a)

Figure 7 (continued). Comparison of observed (left bar) and 2002 Base G modeled (right bar) daily extinction for Caney Creek (CACR), Arkansas during (a) Best 20% (B20%) and (b) Worst 20% (W20%) days in 2002. CENRAP results on the W20% days are shown in (C).

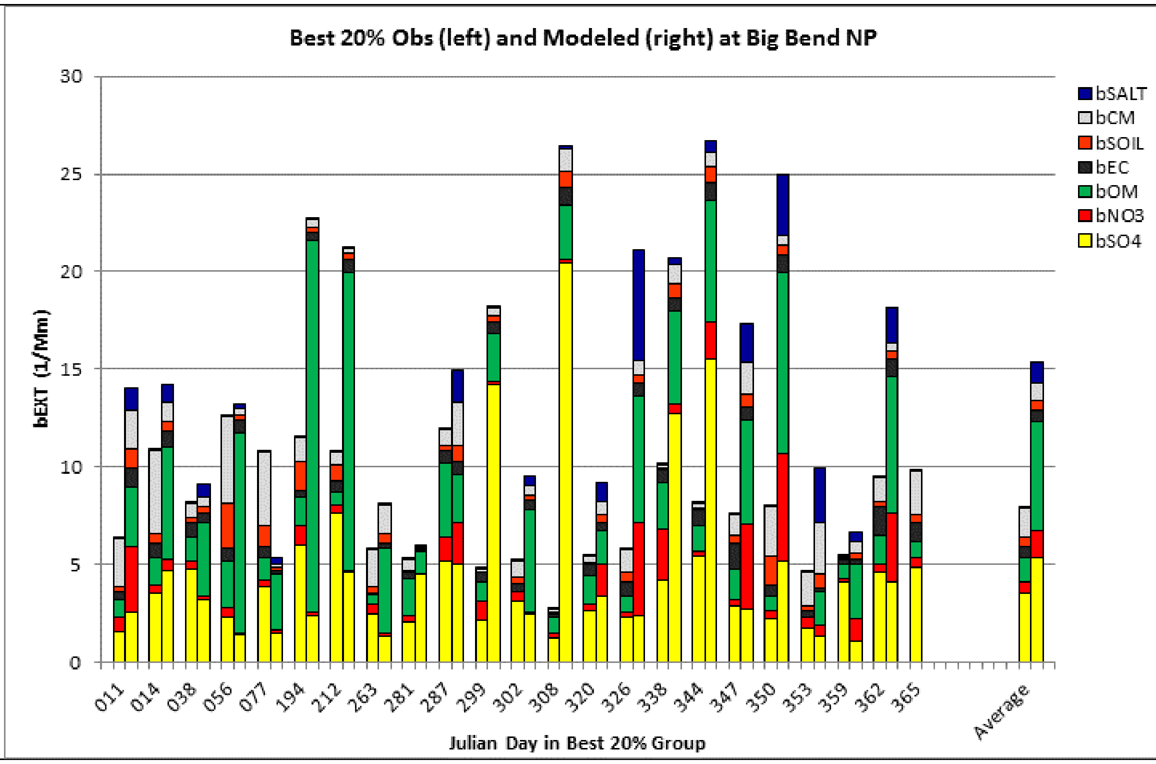


(b)

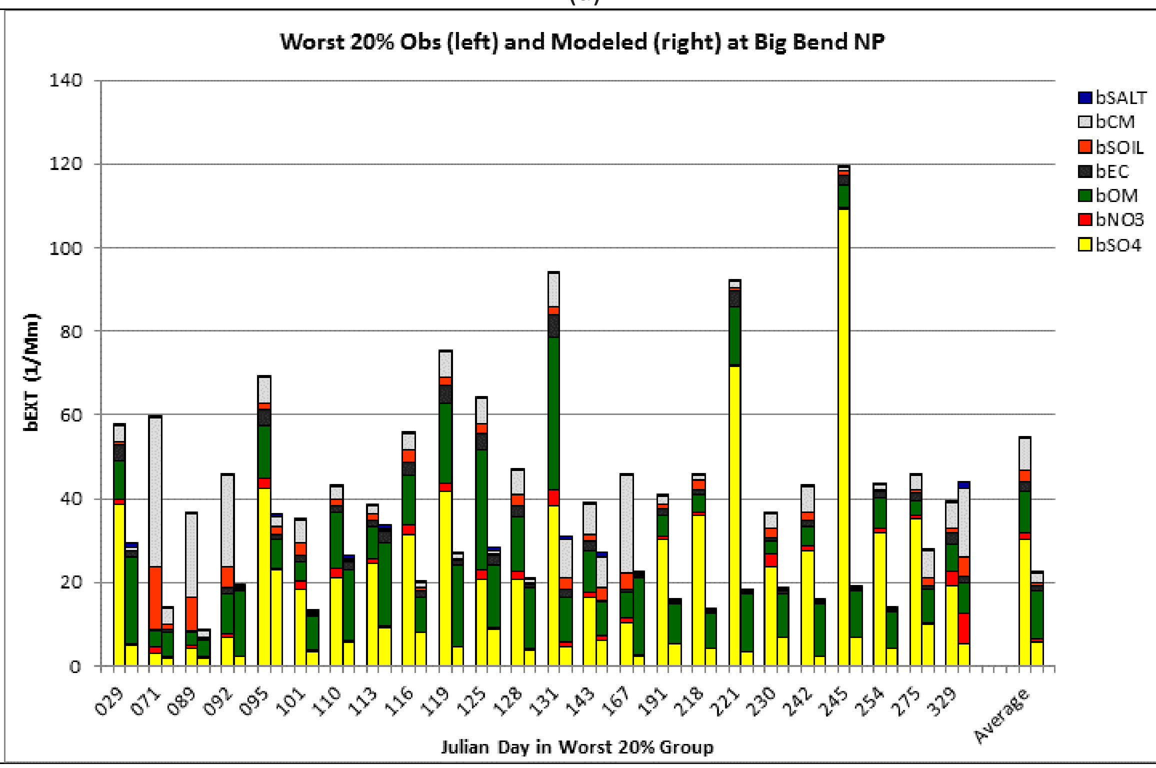


(c)

Figure 7 (completed). Comparison of observed (left bar) and 2002 Base G modeled (right bar) daily extinction for Caney Creek (CACR), Arkansas during (a) Best 20% (B20%) and (b) Worst 20% (W20%) days in 2002. CENRAP results on the W20% days are shown in (C).

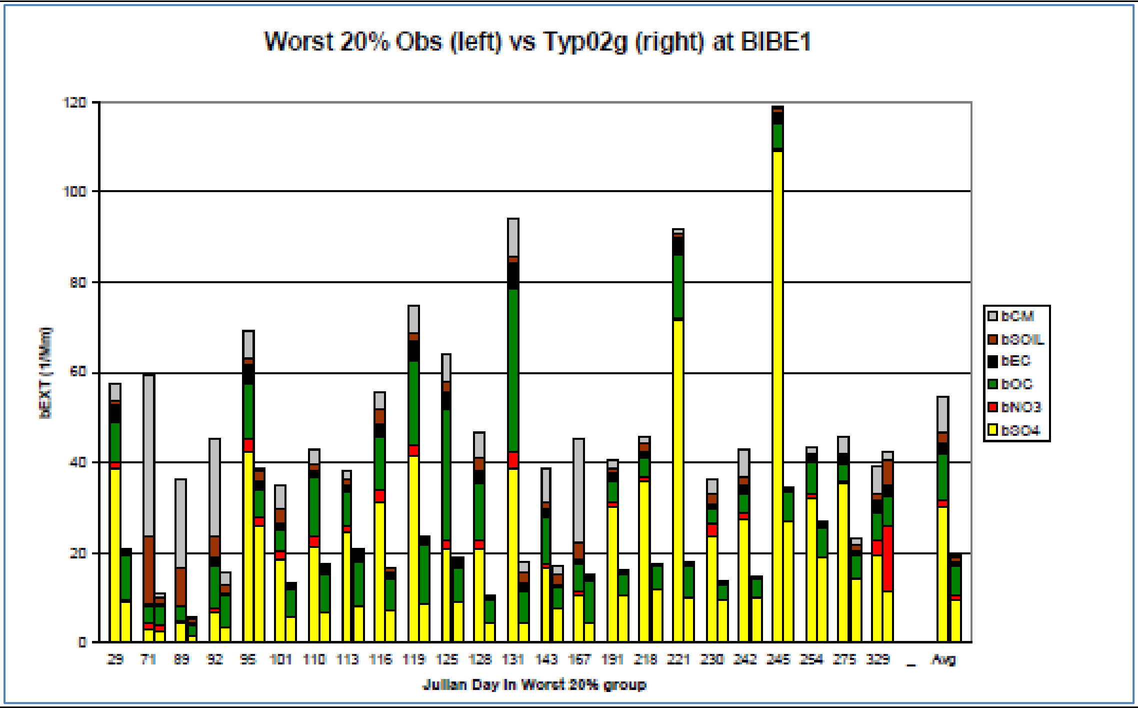


(a)



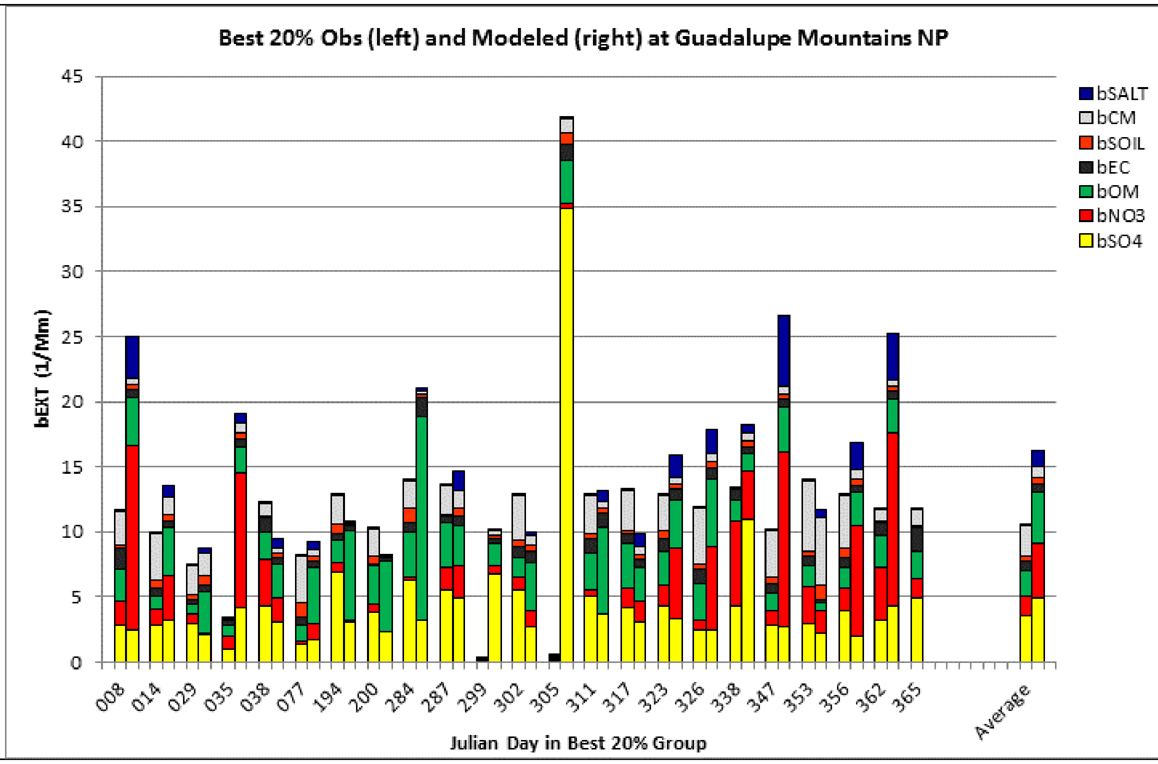
(b)

Figure 8 (continued). Comparison of observed (left bar) and 2002 Base G modeled (right bar) daily extinction for Big Bend National Park (BIBE), Texas during (a) Best 20% (B20%) and (b) Worst 20% (W20%) days in 2002. CENRAP results on the W20% days are shown in (C).

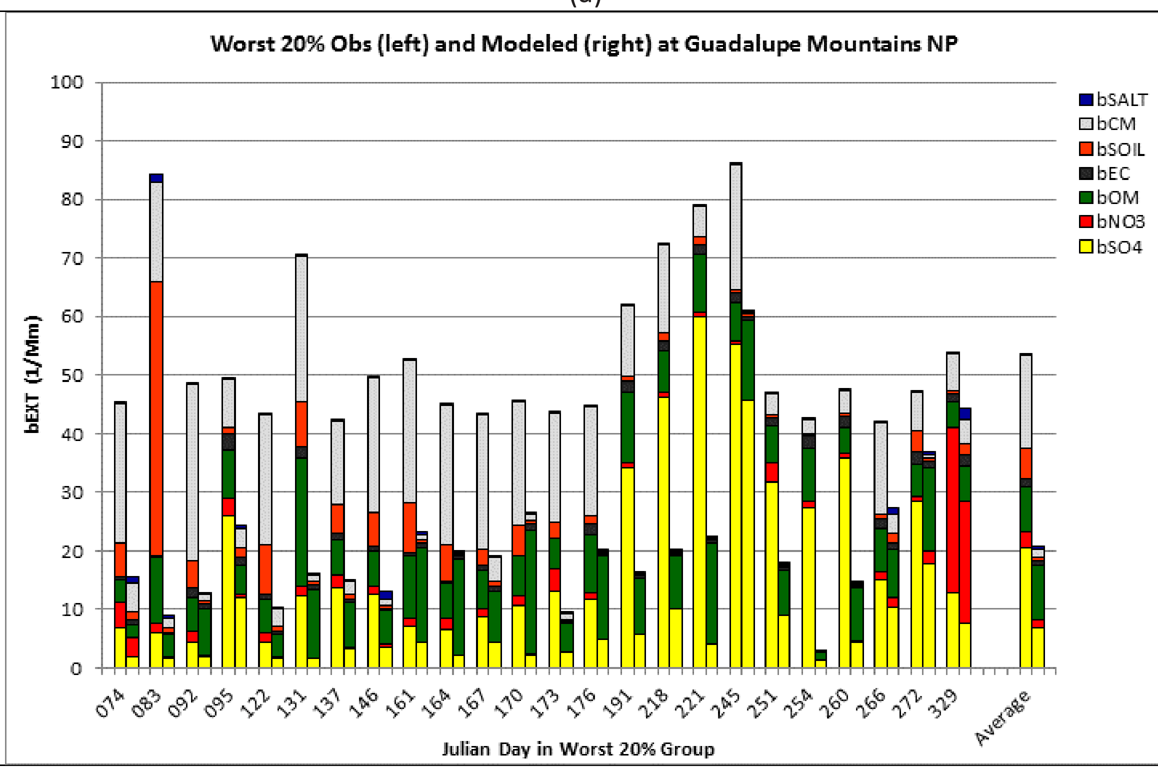


(c)

Figure 8 (completed). Comparison of observed (left bar) and 2002 Base G modeled (right bar) daily extinction for Big Bend National Park (BIBE), Texas during (a) Best 20% (B20%) and (b) Worst 20% (W20%) days in 2002. CENRAP results on the W20% days are shown in (C).

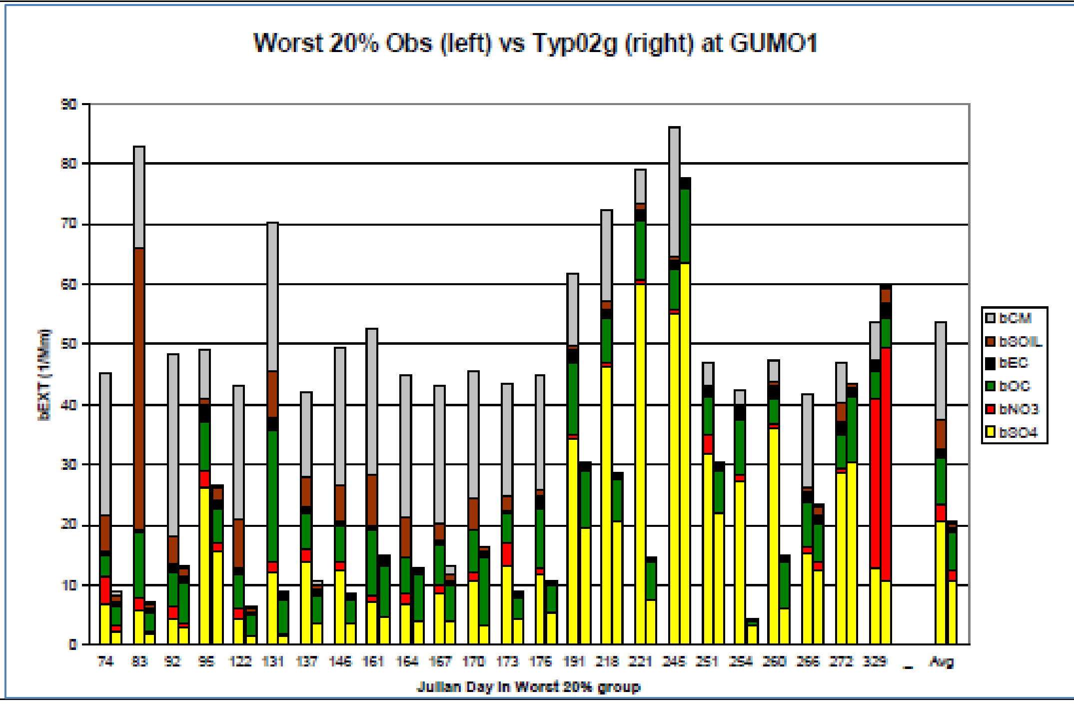


(a)



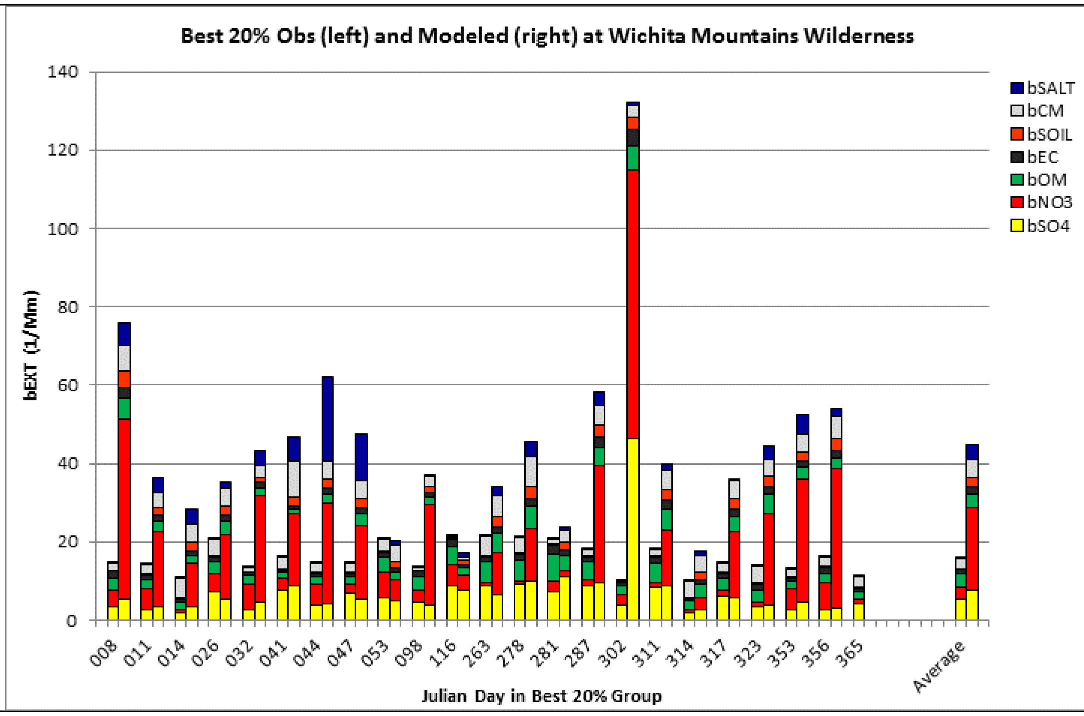
(b)

Figure 9 (continued). Comparison of observed (left bar) and 2002 Base G modeled (right bar) daily extinction for Big Guadalupe Mountains National Park (GUMO), Texas during a) Best 20% (B20%) and (b) Worst 20% (W20%) days in 2002. CENRAP results on the W20% days are shown in (C).

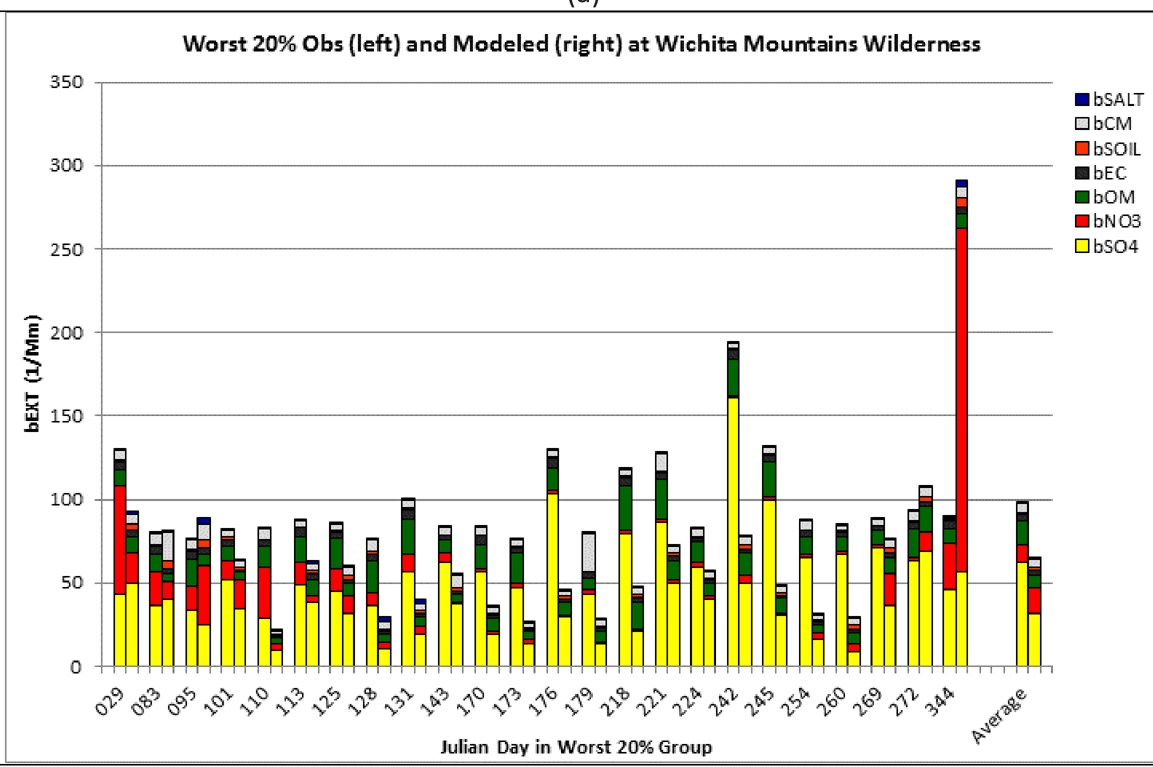


(c)

Figure 9 (completed). Comparison of observed (left bar) and 2002 Base G modeled (right bar) daily extinction for Big Guadalupe Mountains National Park (GUMO), Texas during a) Best 20% (B20%) and (b) Worst 20% (W20%) days in 2002. CENRAP results on the W20% days are shown in (C).

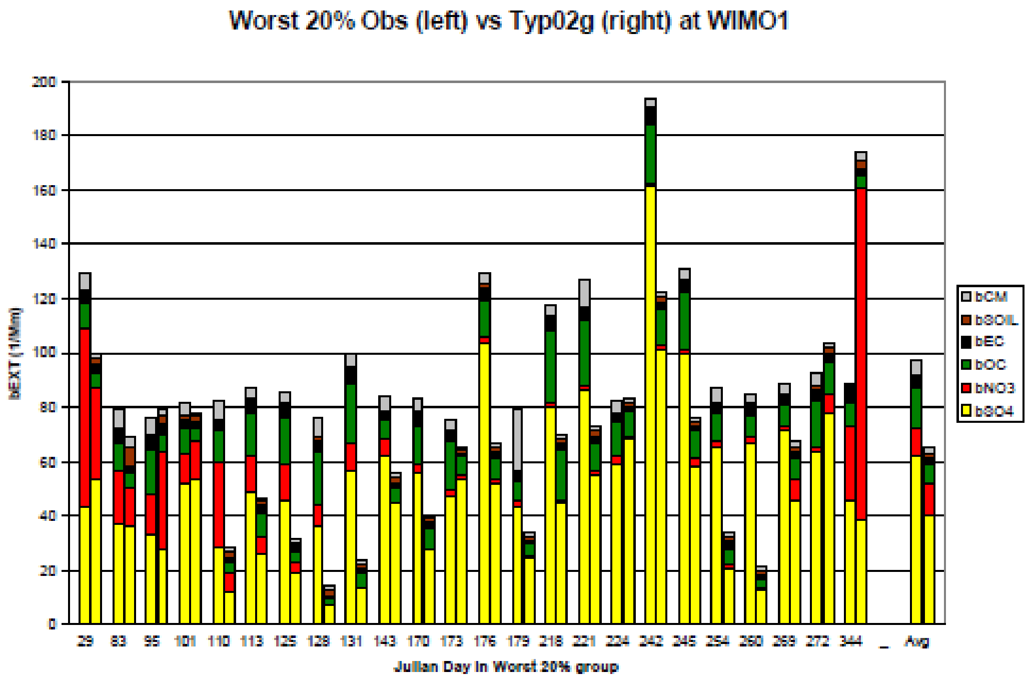


(a)



(b)

Figure 10 (continued). Comparison of observed (left bar) and 2002 Base G modeled (right bar) daily extinction for Wichita Mountains Wilderness Area (WIMO), Oklahoma during a) Best 20% (B20%) and (b) Worst 20% (W20%) days in 2002. CENRAP results on the W20% days are shown in (C).



(c)

Figure 10 (completed). Comparison of observed (left bar) and 2002 Base G modeled (right bar) daily extinction for Wichita Mountains Wilderness Area (WIMO), Oklahoma during a) Best 20% (B20%) and (b) Worst 20% (W20%) days in 2002. CENRAP results on the W20% days are shown in (C).

SUMMARY

Air quality modeling results for the 2002 baseline simulations are presented by pollutant of concern, including ozone and PM. Peak values for both ozone and PM outside of urban areas are influenced by fire emissions as indicated by high organic particulate concentrations. Overall, the air quality maps show predicted ozone and PM concentrations within reasonable ranges. Additional analysis would have to be undertaken to examine in details the model's ability to treat ozone and fine particulate.

The model evaluation focused on the model's ability to predict the components of light extinction at the Class I areas. Similar visibility analysis by CENRAP concluded that the CMAQ 2002 36 km model appears to be good enough to make future-year projections for changes in SO4, NO3, EC and OMC at the rural Class I areas. The CAMx 2002 model appears to be comparable to the CENRAP 2002 model on the worst 20% days. Underestimation bias of sulfate is seen in both simulations with a larger bias seen in this study. Performance for Soil and especially CM is suspect and care should be taken in interpreting these modeling results.

REFERENCES

ENVIRON. 2012. "User's Guide – Comprehensive Air-quality Model with extensions, Version 5.40." ENVIRON International Corporation, Novato, California. (Available at http://www.camx.com).

ENVIRON and CERT. 2007. "Technical Support Document for CENRAP Emissions and Air Quality Modeling to Support Regional Haze State Implementation Plans", prepared for the Central Regional Air Planning Association, prepared by ENVIRON International Corporation, and the University of California, Riverside. September 12.

EPA. 2003. Guidance for Estimating Natural Visibility Conditions under the Regional Haze Rule. EPA-454/B-03-005. U.S. Environmental Protection Agency, Research Triangle Park, NC.

FLAG. 2010. Federal Land Managers' Air Quality Related Values Work Group (FLAG) Phase I report-Revised (2010). Natural Resource Report NPS/NRPC/NRR—2010/232

Morris, R.E., G.E. Mansell, B. Koo, G. Tonnesen, M. Omary and Z. Wang. 2004. Modeling Protocol for the CENRAP 2002 Annual Emissions and Air Quality Modeling, Draft 2.0. (http://pah.cert.ucr.edu/aqm/cenrap/docs/CENRAP_Draft2.0_Modeling_Protocol_12084.pdf). December 8.

Morris, R.E. and G. Tonnesen. 2004. Quality Assurance Project Plan (Draft) for Central Regional Air Planning Association (CENRAP) Emissions and Air Quality Modeling. (http://pah.cert.ucr.edu/aqm/cenrap/docs/CENRAP_QAPP_Nov_24_2004.pdf). December 23.

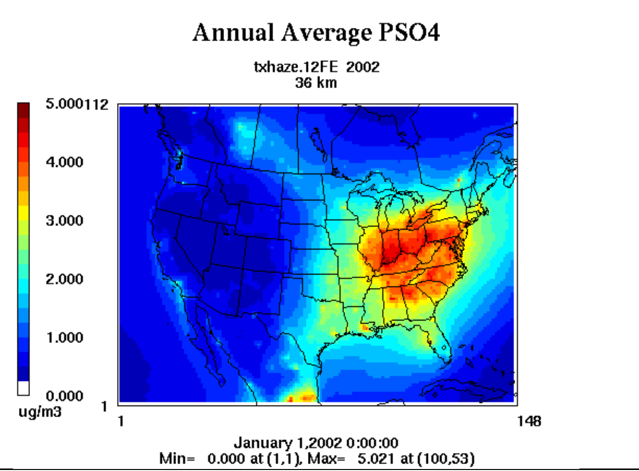
Morris, R.E., A. Hoats, S. Lau, B. Koo, G. Tonnesen, C-J. Chien and M. Omary. 2005. Air Quality Modeling Analysis for CENRAP – Preliminary 2002 Base Case CMAQ and CAMx Modeling of the Continental US 36 km Domain and Model Performance Evaluation. ENVIRON International Corporation, Novato, California. April 30.

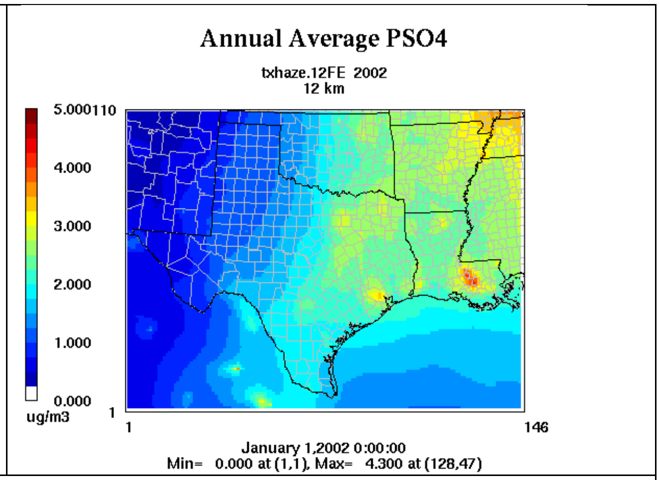
Pitchford, M.L., Malm, W.C., Schichtel, B.A., Kumar, N., Lowenthal, D., and Hand, J.L. 2007. Revised algorithm for estimating light extinction from IMPROVE particle speciation data. Journal of the Air and Waste Management Association. 57, 1326-1336.

APPENDIX A

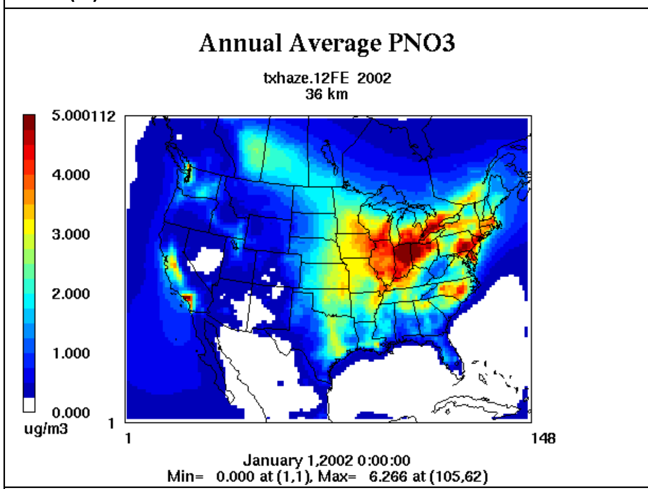
Annual Average PM Constituents from the CAMx 2002 Base Case results

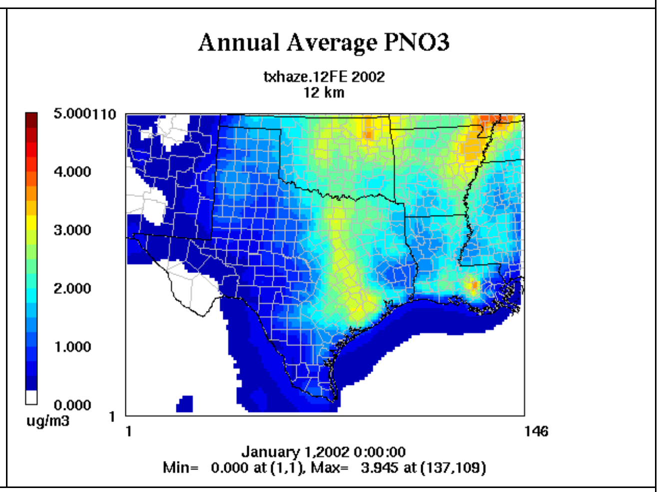
Appendix A: Annual Average PM Constituents from the CAMx 2002 Base Case results



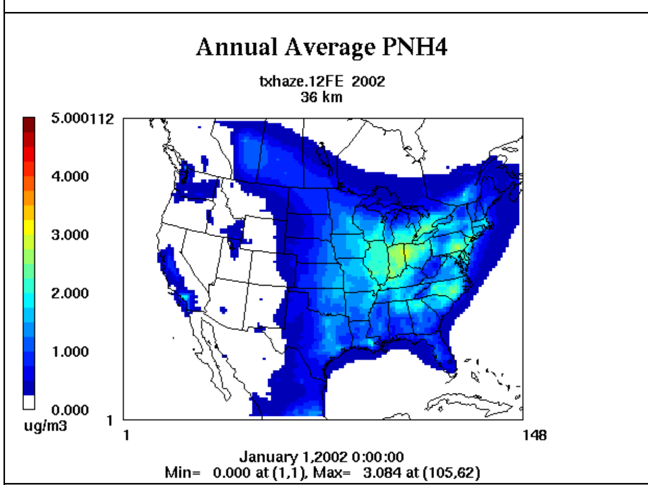


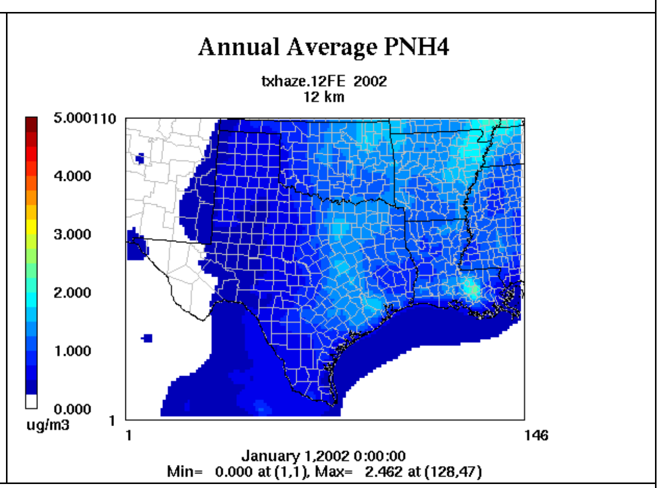
(a) Sulfate



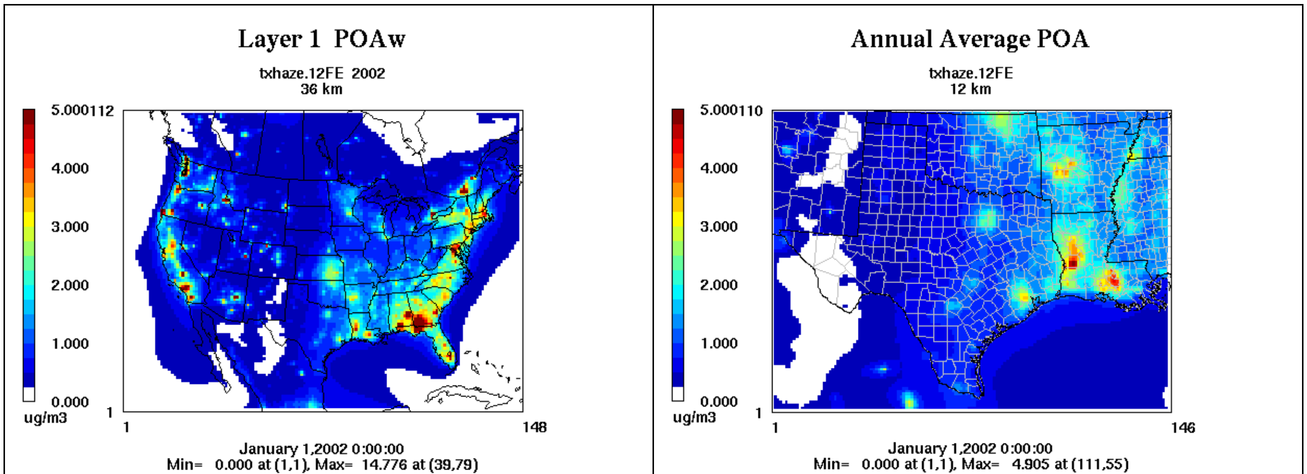


(b) Nitrate

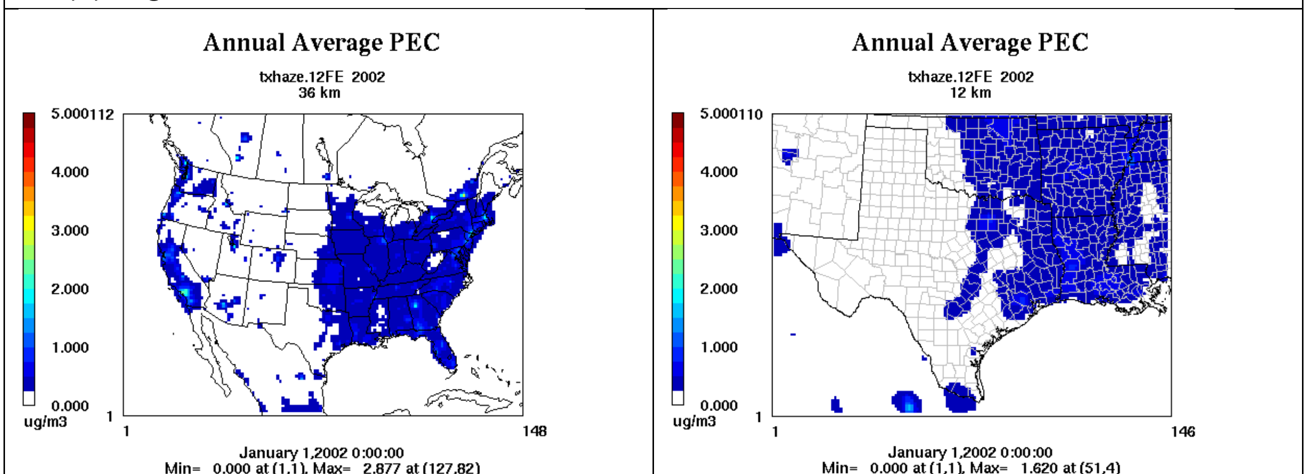




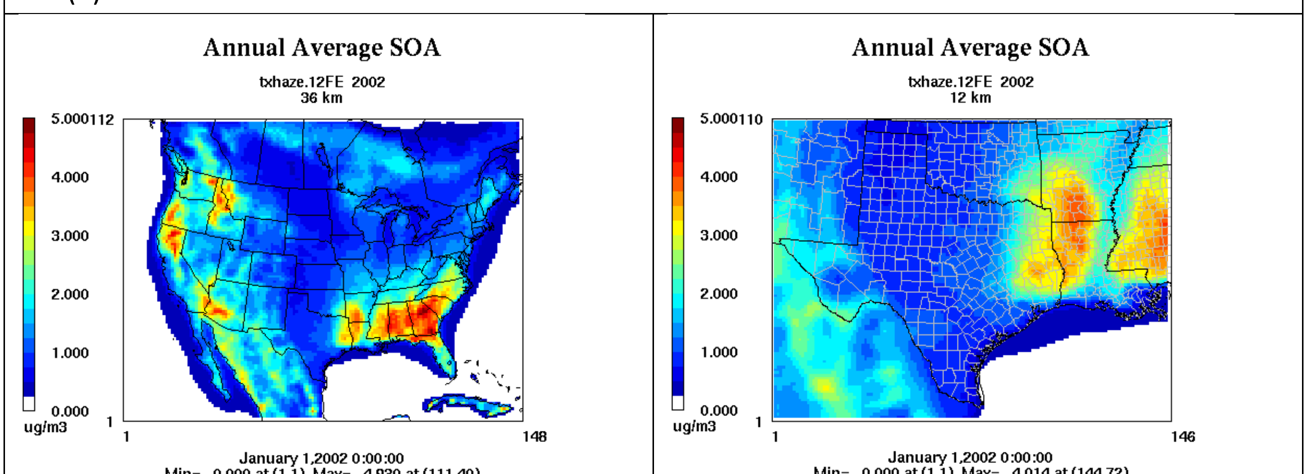
(c) Ammonium



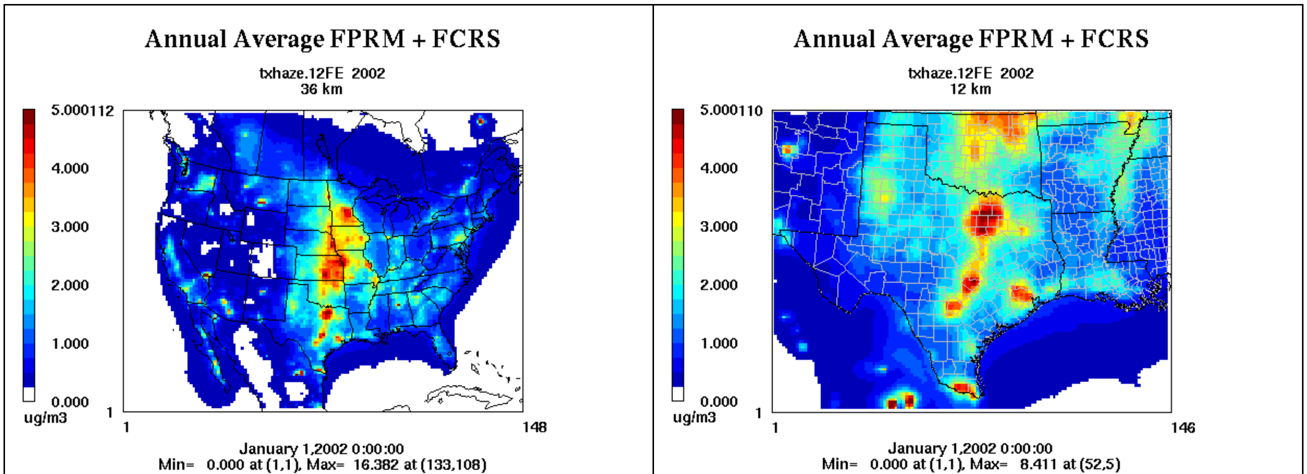
(d) Organic aerosols



(e) Elemental Carbon



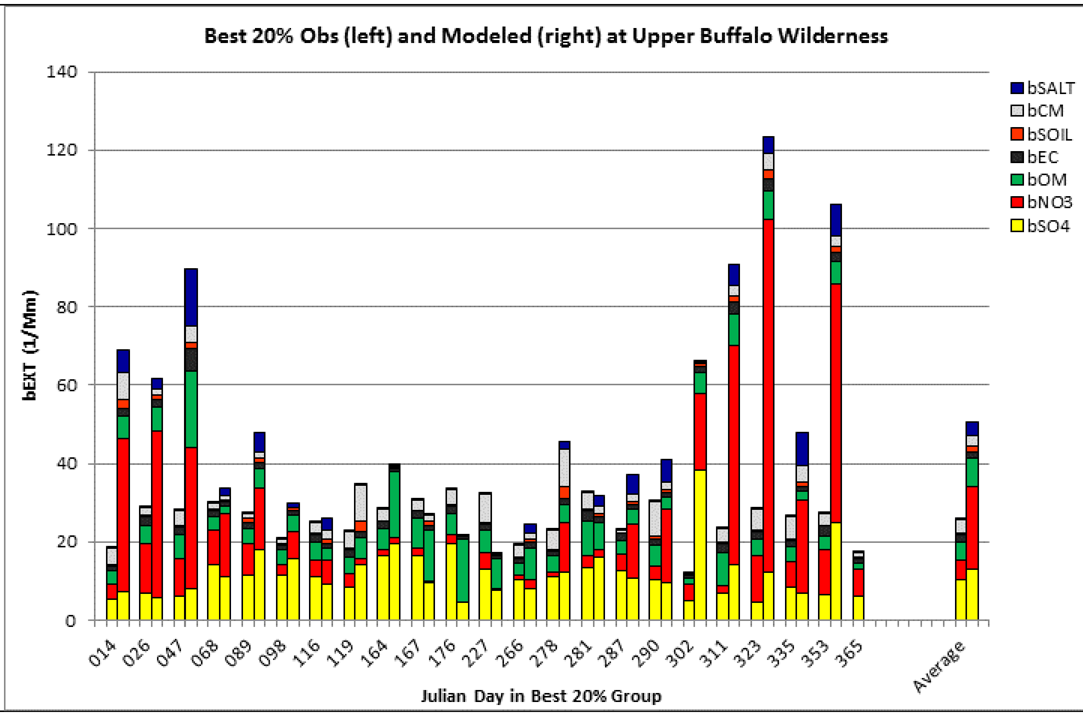
(f) Secondary organic aerosols



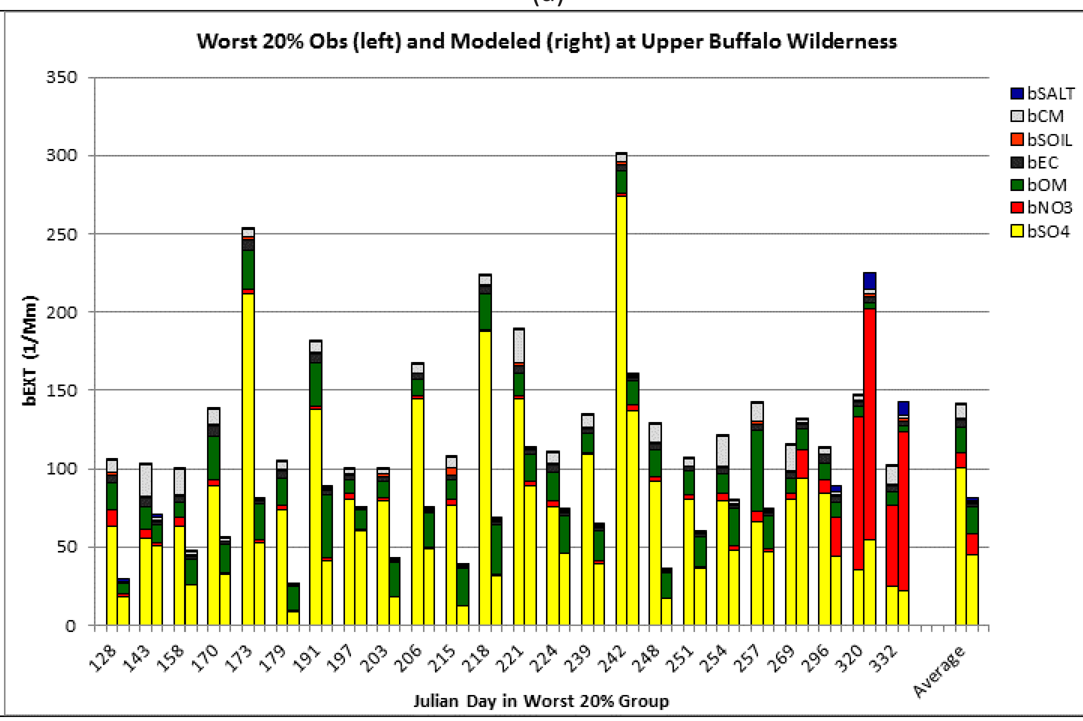
(g) Other fine particulates and fine crustal materials

APPENDIX B
Visibility Analysis for 2002 Typical Base G Emission Scenario

Appendix B: Visibility Analysis for 2002 Typical Base G Emission Scenario

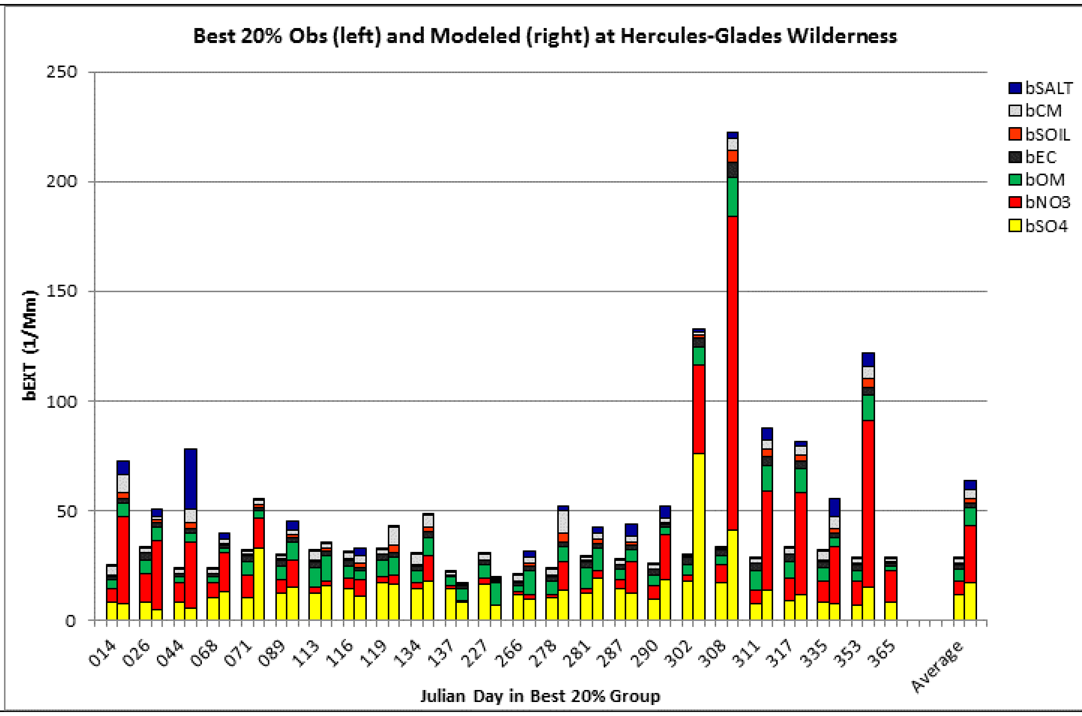


(a)

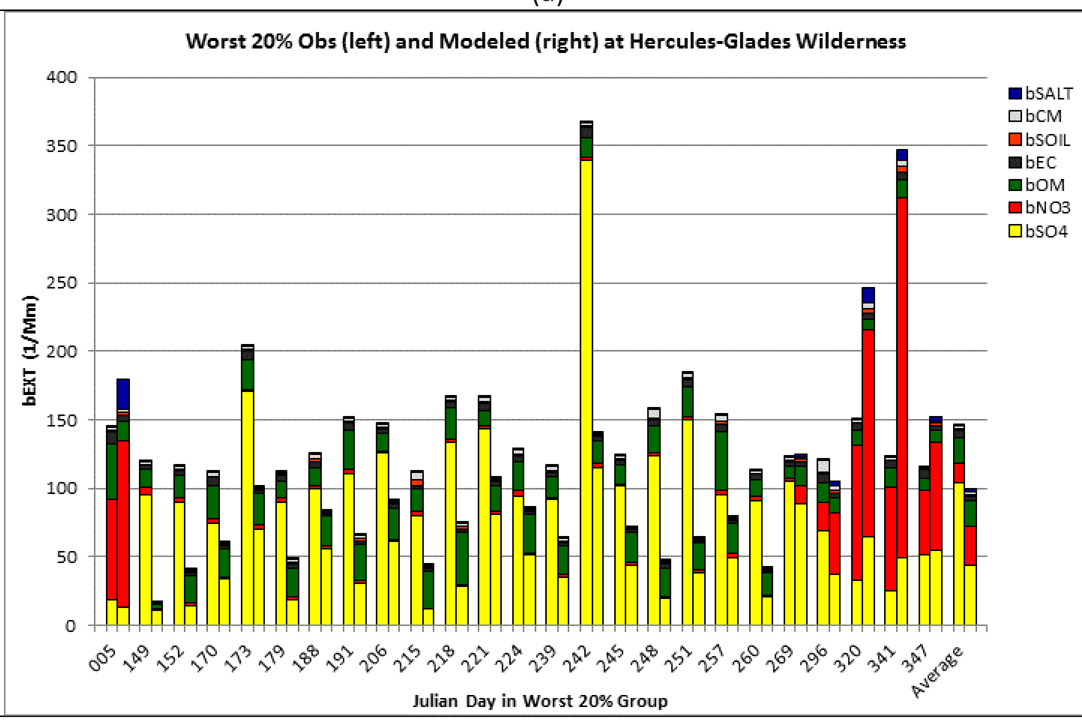


(b)

Figure B-1. Comparison of observed (left bar) and 2002 Base G modeled (right bar) daily extinction for Upper Buffalo Wilderness (UPBU), Arkansas during (a) Best 20% (B20%) and (b) Worst 20% (W20%) days in 2002.

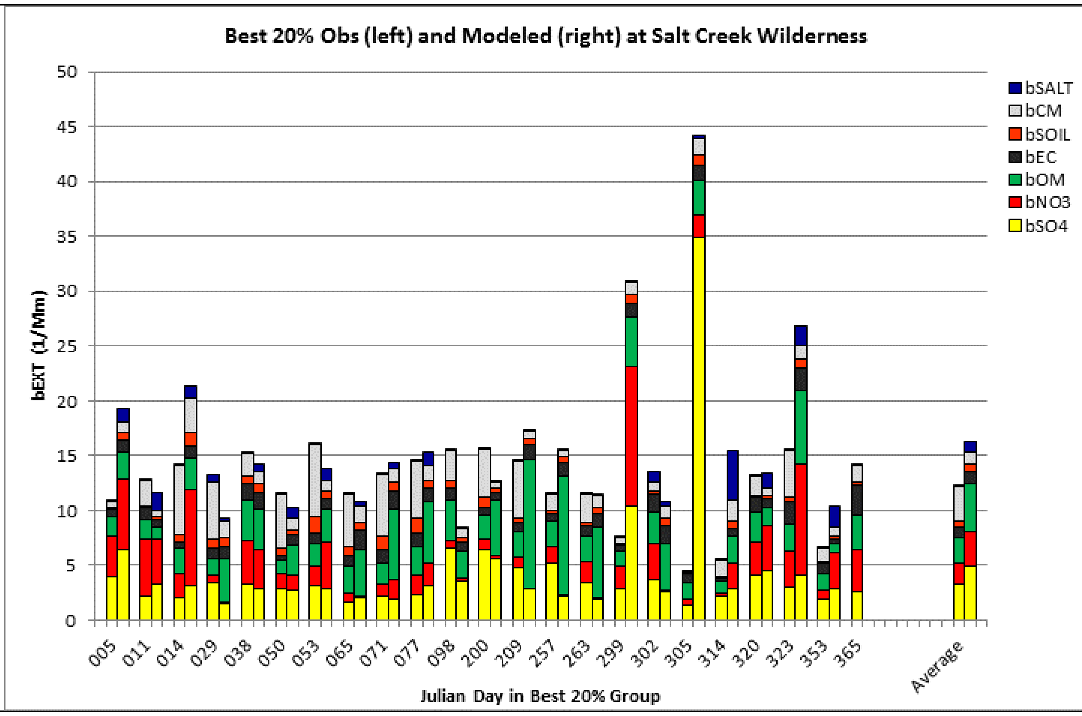


(a)

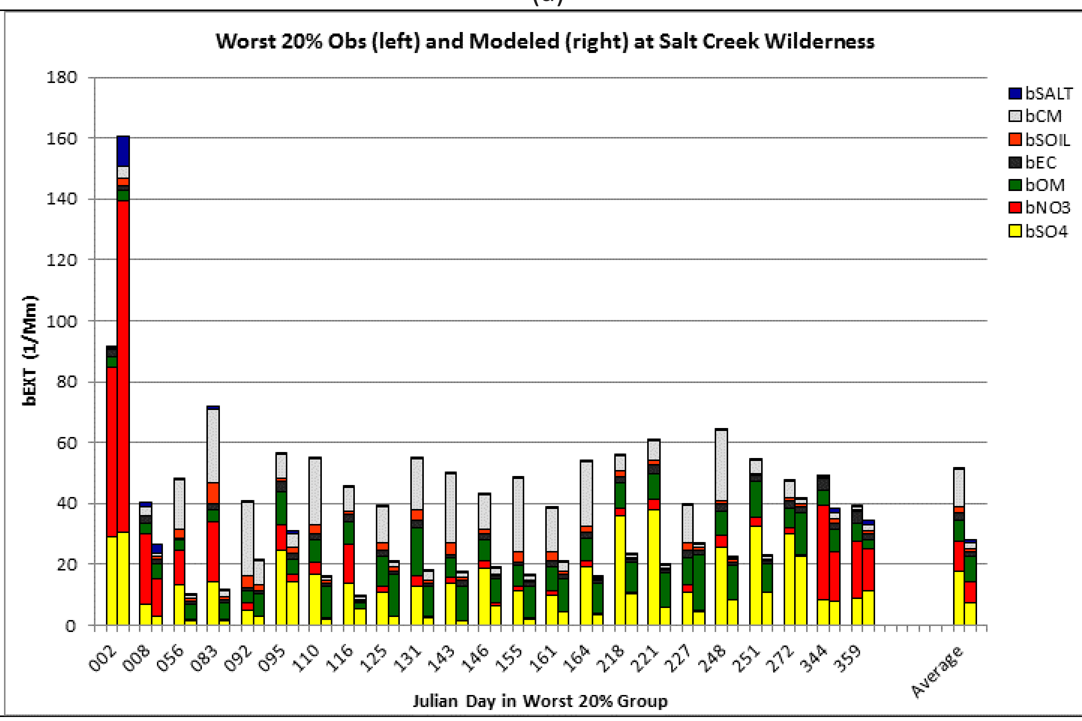


(b)

Figure B-2. Comparison of observed (left bar) and 2002 Base G modeled (right bar) daily extinction for Hercules-Glades Wilderness (HUGL), Missouri during (a) Best 20% (B20%) and (b) Worst 20% (W20%) days in 2002.

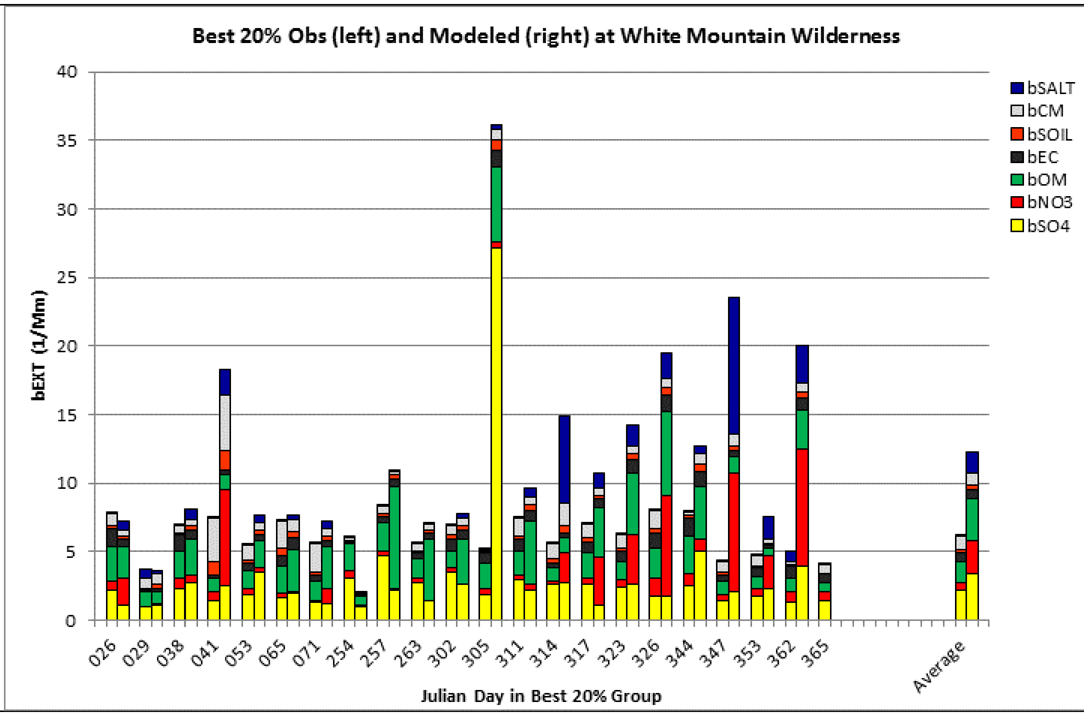


(a)

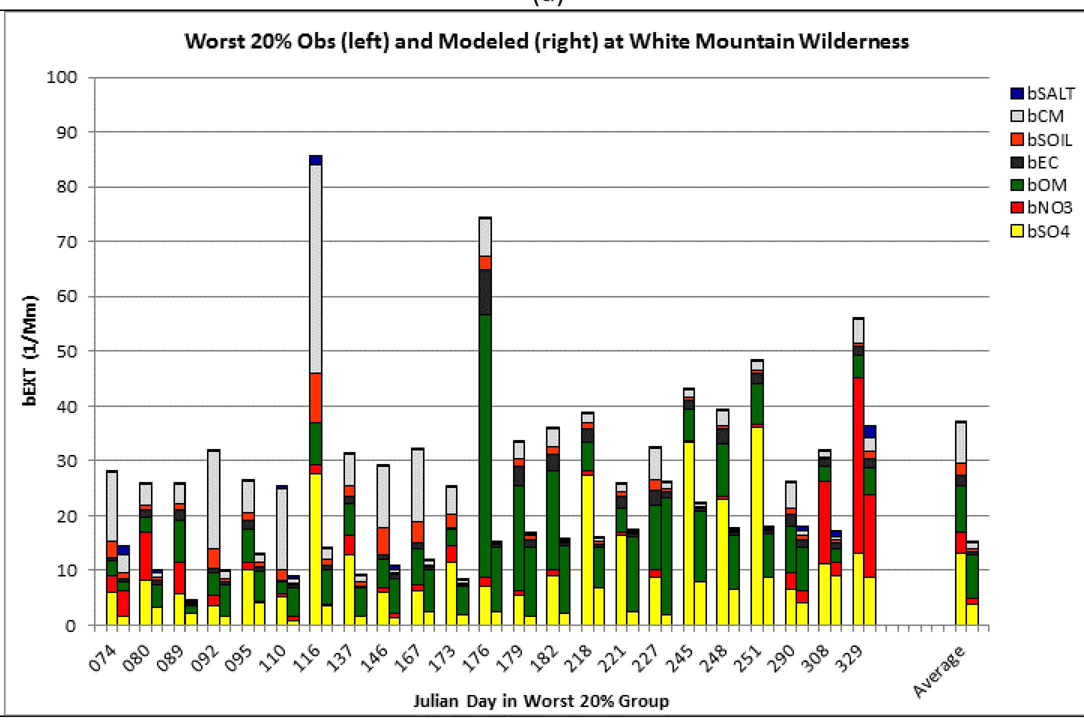


(b)

Figure B-3. Comparison of observed (left bar) and 2002 Base G modeled (right bar) daily extinction for Salt Creek Wilderness (SACR), New Mexico during (a) Best 20% (B20%) and (b) Worst 20% (W20%) days in 2002.

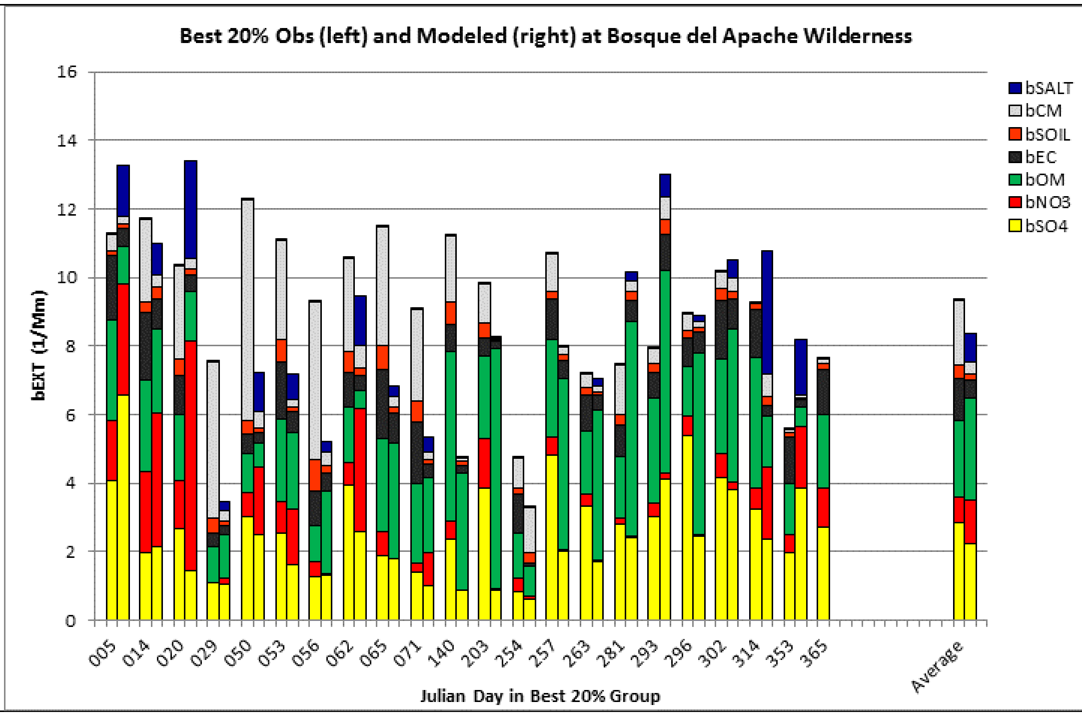


(a)

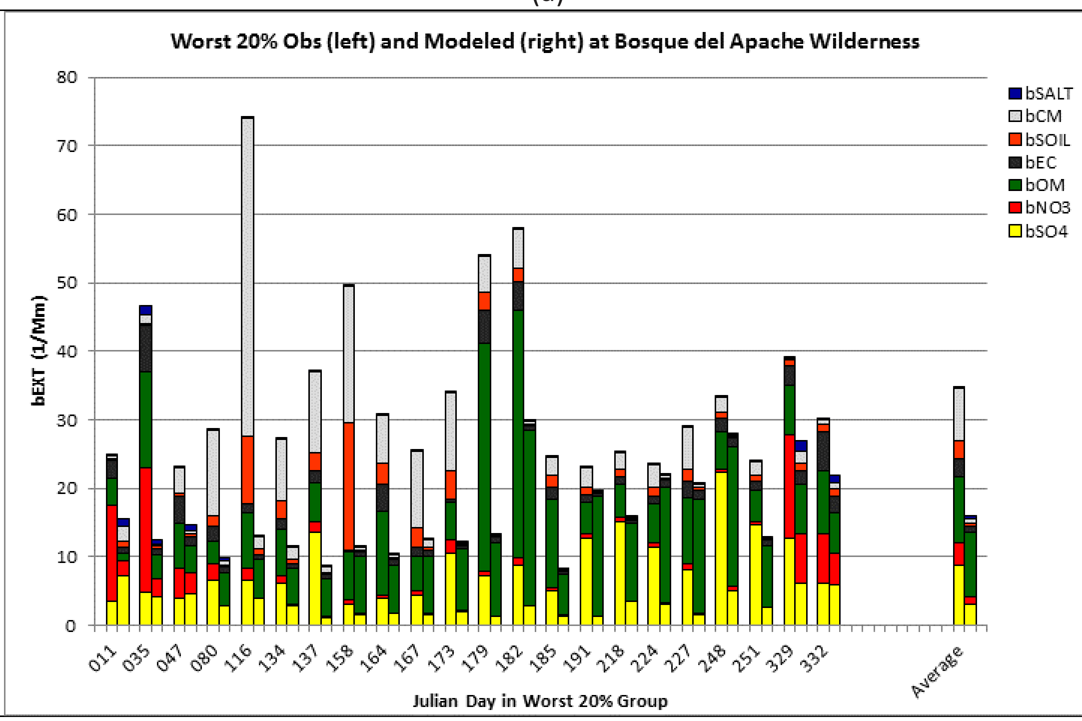


(b)

Figure B-4. Comparison of observed (left bar) and 2002 Base G modeled (right bar) daily extinction for White Mountains Wilderness (WHIT), New Mexico during (a) Best 20% (B20%) and (b) Worst 20% (W20%) days in 2002.

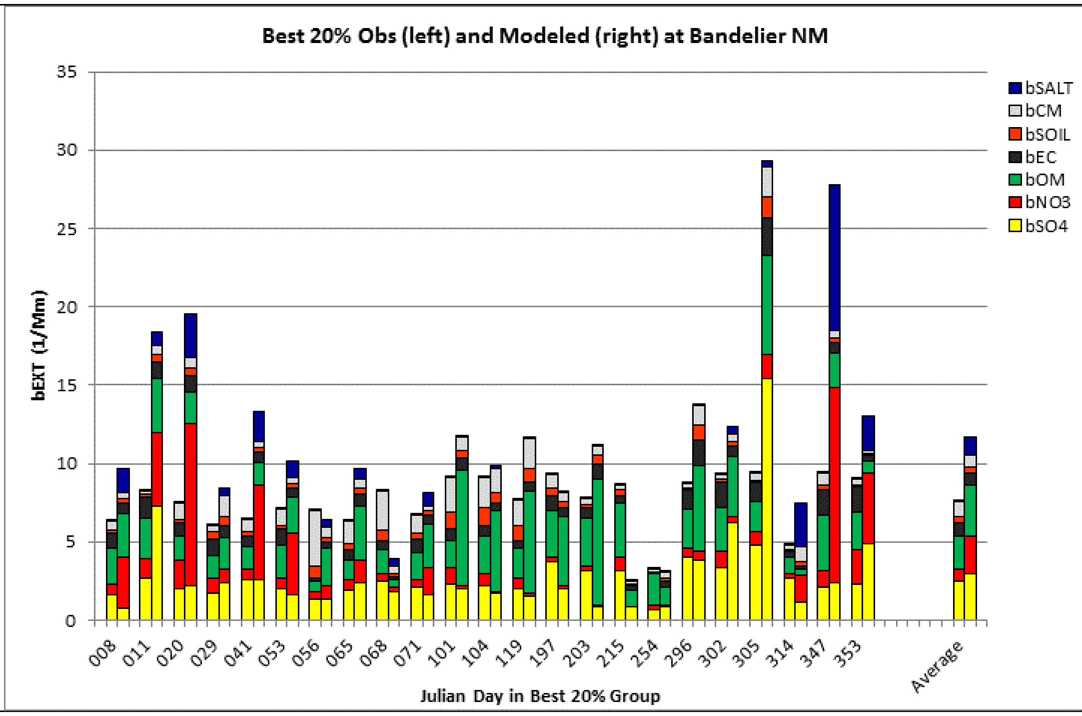


(a)

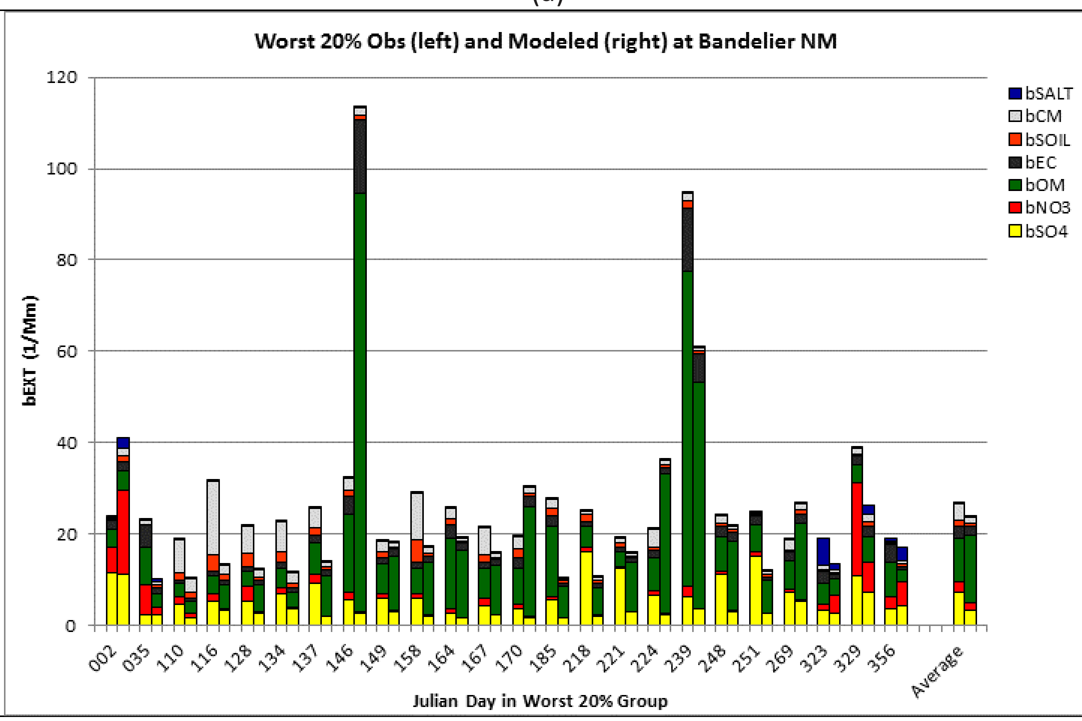


(b)

Figure B-5. Comparison of observed (left bar) and 2002 Base G modeled (right bar) daily extinction for Bosque del Apache Wilderness (BOAP), New Mexico during (a) Best 20% (B20%) and (b) Worst 20% (W20%) days in 2002.

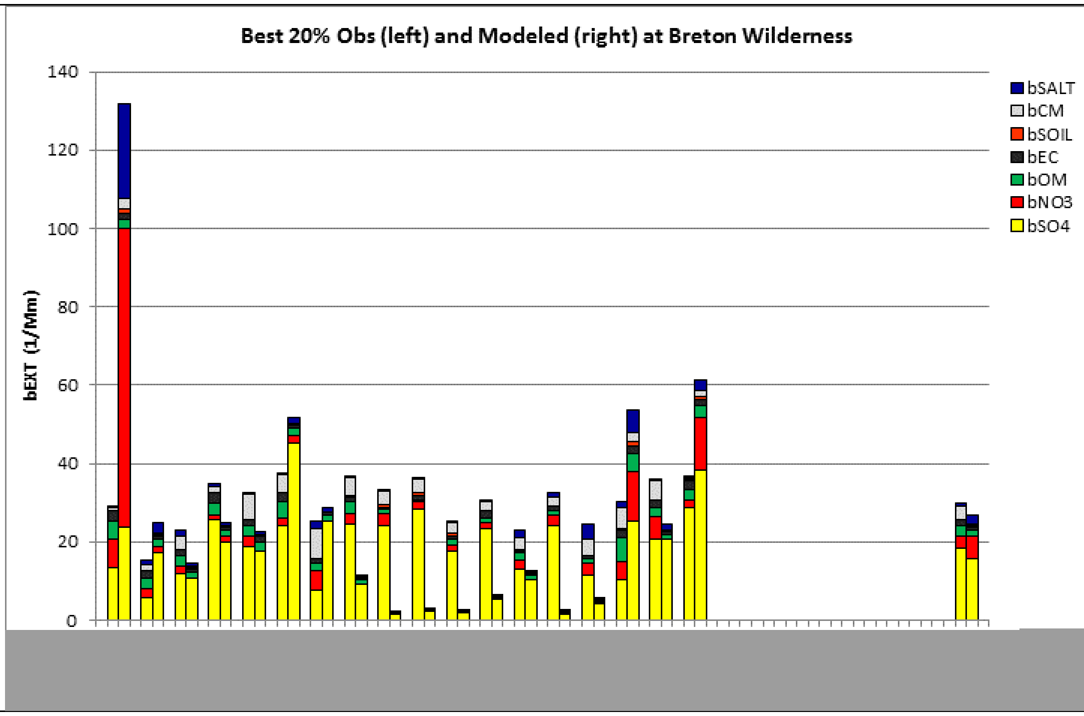


(a)

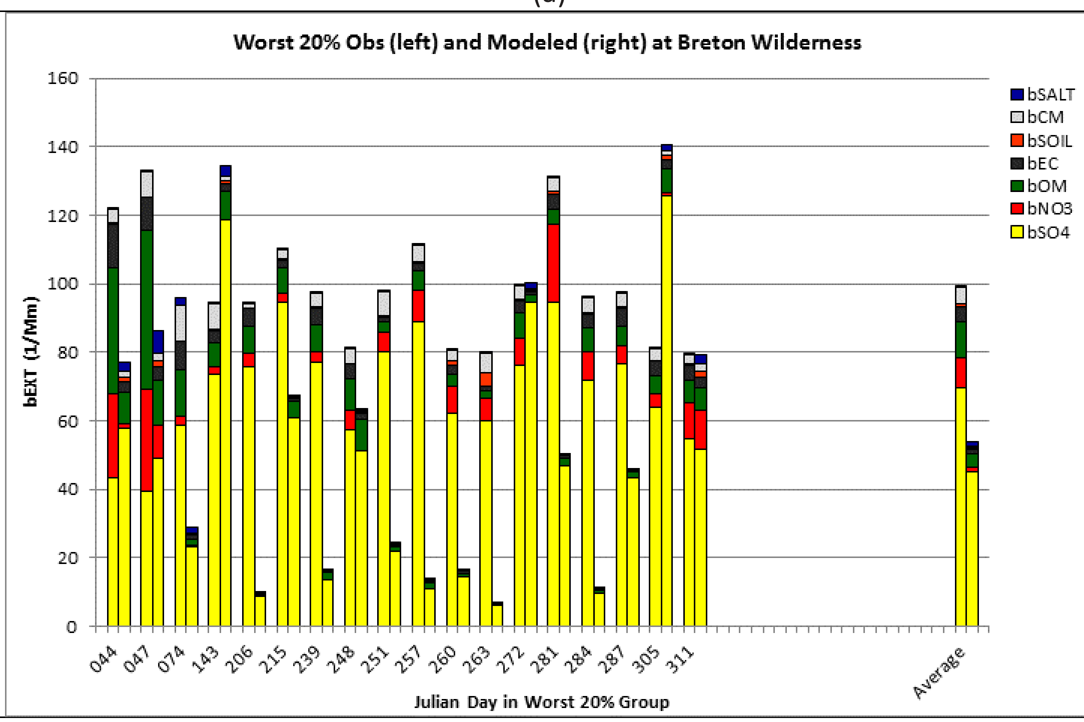


(b)

Figure B-6. Comparison of observed (left bar) and 2002 Base G modeled (right bar) daily extinction for Bandelier Wilderness Area (BAND), New Mexico during (a) Best 20% (B20%) and (b) Worst 20% (W20%) days in 2002.



(a)



(b)

Figure B-7. Comparison of observed (left bar) and 2002 Base G modeled (right bar) daily extinction for Breton Wilderness (BRET), Louisiana during (a) Best 20% (B20%) and (b) Worst 20% (W20%) days in 2002.